

May 2005

# ***Yolo Bypass Water Quality Management Plan Report***



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Prepared under CALFED Watershed Grant, Agreement # 4600001691  
For the City of Woodland

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# EXECUTIVE SUMMARY

The Yolo Bypass ("Bypass") is a leveed, 59,000-acre floodplain, approximately 41 miles long and 1-3 miles wide, parallel to and on the west side of the lower Sacramento River in California's Yolo and Solano Counties (Figure ES-1). The major flood control features are the Fremont and Sacramento Weirs, over which floodwaters in the Sacramento, Feather, and American Rivers spill. Other major inputs to the Bypass include, from north to south, the Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. Urban stormwater runoff and wastewater treatment facility discharges come from the University of California Davis campus and the Cities of Davis, Woodland, and West Sacramento (stormwater only).

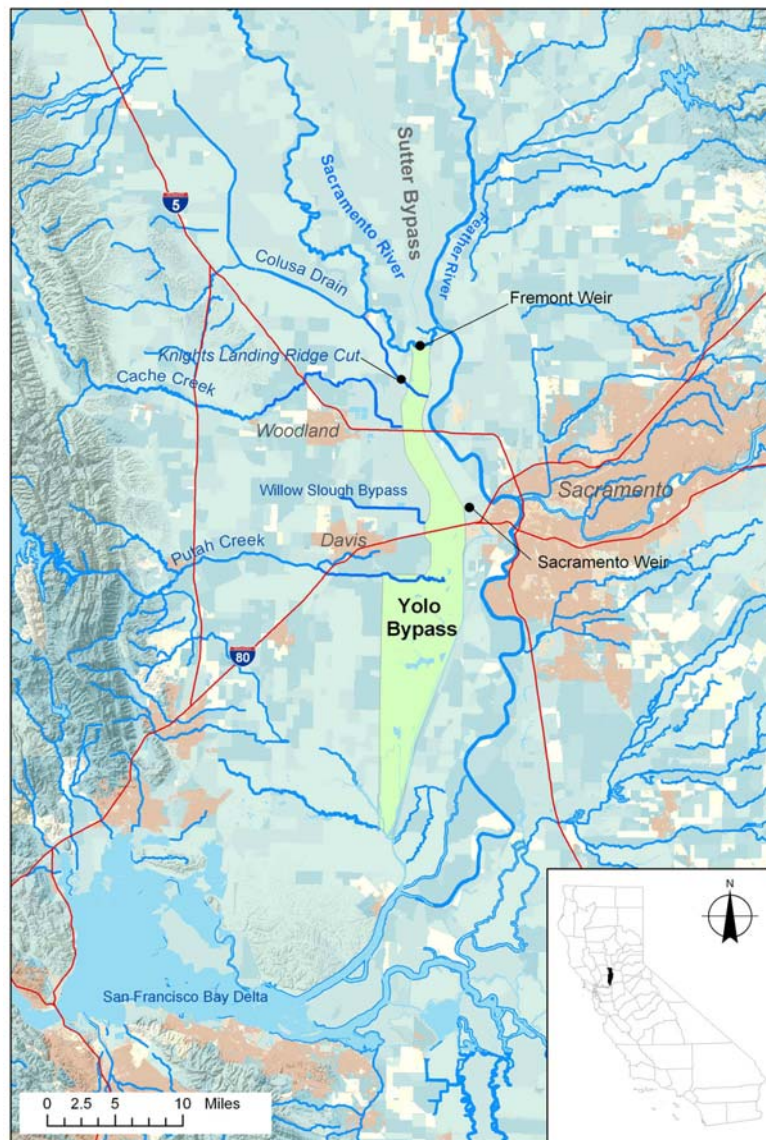


Figure ES-1. Location of the Yolo Bypass with its major tributaries.

The Bypass is a vital flood control feature that protects low-lying areas in the Sacramento area. In addition, it receives water from local drains and creeks, and urban stormwater and wastewater. Water is used beneficially within the Bypass in several ways, most notably agriculture and wildlife habitat. Discharges to the San Francisco Bay-Delta also contribute to regional drinking water supplies.

The objective of this project was to develop a comprehensive water quality management plan for the Bypass. The general steps followed to develop the plan were to:

- Identify through review of existing information and stakeholder input current pollutants of concern (POCs) for the Bypass;
- Conduct surface water quality monitoring to help quantify POCs and their major sources;
- Identify and evaluate effective, implementable control measures for reducing POC concentrations and loads;
- Investigate, if necessary, the applicability of current water quality criteria for the POCs and the feasibility of developing site-specific objectives (SSOs);
- Involve stakeholders regarding POCs and potential control measures;
- Produce a Water Quality Management Plan containing a recommended implementation program to address POCs that are degrading surface water quality.

The POCs were identified by stakeholders after a cursory review of available data. The identified POCs were then monitored over a one-year period. Based on these monitoring results and stakeholder input, the POCs were prioritized as shown in Table ES-1.

**Table ES-1. Prioritization of the POCs.**

POC	Priority		
	High	Medium	Low
<b>Bacteria</b>	X		
Total coliform			
Fecal coliform			
E. coli			
<b>Boron</b>	X		
<b>Metals</b>			
Aluminum	X		
Chromium			X
Copper			X
Lead			X
Mercury	X		
Selenium			X
<b>Nitrate</b>			X
<b>Organic Carbon</b>		X	
Total organic carbon			
Dissolved organic carbon			
<b>Pesticides and Herbicides</b>			
OCs (DDE and DDT)		X	
OPs (Chlorpyrifos and Diazinon)		X	
Carbamates (Diuron and Methomyl)			X
<b>Salinity</b>	X		
<b>Total Suspended Solids (TSS)</b>			X

The goal of this plan is to set forth a series of actions that will result in achievement of water quality objectives appropriate for the Yolo Bypass. The most stringent, potentially applicable water quality objectives found in the Basin Plan, local NPDES permits, and proposed Basin Plan amendments are the basis of the objectives compared with monitoring data. Potential options for addressing the POCs to meet those objectives are as follows, generally in order of most preferable first.

- **Implement control measures.** Implement feasible and cost-effective control measures such as described previously in this report.
- **Undertake research and special studies.** Conduct focused studies that improve the conceptual model for certain POCs or that aid in quantifying effectiveness of control measures.
- **Monitor water quality.** Monitor water quality to improve our ability to detect changes in water quality and to quantify linkages in the conceptual models for various POCs.
- **Conduct site-specific objective or beneficial use studies.** Address POCs coming from predominately natural and uncontrollable sources.
- **Participate in future stakeholder activities.** Participate in related stakeholder forums and in the development of plans and policies that directly impact water quality in the Bypass.

The resulting plan provides an adaptive management framework in which some recommended actions aim to reduce POC loads while others would provide for additional information for improving our ability to effectively manage water quality in the Bypass. Actions described under these options address all high and medium priority POCs. Future stakeholder activities are also recommended to foster collaboration and participation as information improves the ability to manage water quality.

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# LIST OF ACRONYMS

BMP – Best Management Practice  
CCRMP – Cache Creek Resources Management Plan  
cfs – cubic feet per second  
CTR – California Toxics Rule  
CVRWQCB – Central Valley Regional Water Quality Control Board  
DOC – Dissolved Organic Carbon  
DWR – California Department of Water Resources  
EC – electro-conductivity  
IRWMP – Integrated Water Resources Management Plan  
MGD – million gallons per day  
NAWQA – National Water Quality Assessment Program  
NPDES – National Pollutant Discharge Elimination System  
OC – organochlorine  
OP – organophosphate  
POC – Pollutant of Concern  
RO – Reverse Osmosis  
SSO – Site-specific Objective  
SWPPP – Storm Water Pollution Prevention Plans  
TDS – Total Dissolved Solids  
TMDL – Total Maximum Daily Load  
TOC – Total Organic Carbon  
TSS – Total Suspended Solids  
UAA – Use Attainability Analysis  
UC Davis – University of California, Davis  
USBLM – United States Bureau of Land Management  
USEPA – United States Environmental Protection Agency  
USGS – United States Geological Survey  
WER – Water Effects Ratio  
YBWA – Yolo Bypass Wildlife Area

# ACKNOWLEDGEMENTS

Funding for this project was provided by CalFed through Grant #WSP01-FP-0073, and from the City of Woodland, which provided in-kind funding associated with the CalFed grant, as well as additional funds for supplemental monitoring. The City of Davis also provided funding for the supplemental monitoring and related activities.

The CalFed project liaison was Casey Walsh Cady of the California Department of Food and Agriculture. Stefan Lorenzato of the California Department of Water Resources served as CalFed Contract Manager. William Ray of the State Water Resources Control Board was the CalFed QA Officer.

The City of Woodland Project Manager was Gary Wegener. Principal project contacts for the City of the Woodland were Mitch Dion and Christine Engel. Keith Smith was the principal contact for the City of Davis.

The City of Woodland contracted with Larry Walker Associates to perform many of the tasks funded by the grant. Contractor project managers were Armand Ruby and Tess Dunham of LWA. Chris Erichsen was responsible for monitoring program coordination, and contributed in many ways throughout the project. Claus Suverkropp served as Contractor QA officer. Stephen McCord was the principal author of the plan. Chuck Dudley served as subconsultant to LWA for agricultural activities and processes.

The Yolo Basin Foundation, led by Robin Kulakow, provided logistical support for the Stakeholder Advisory Group meetings. Facilitation of the stakeholder meetings was provided by Armand Ruby, initially with LWA and later with Armand Ruby Consulting.

Reviewers of the draft plan included Marianne Kirkland of the California Department of Water Resources, Petra Marchand of the Yolo County Planning Department, Betty Yee of the Central Valley Regional Water Quality Control Board, Christine Engle of the City of Woodland Department of Public Works, and Armand Ruby of Armand Ruby Consulting.

Collection of monitoring program samples was performed by volunteers led by professional staff from LWA, who also volunteered their time for the sample collection effort. Sample collectors included: Chris Erichsen, Armand Ruby, Stephen McCord, Yazmin O'Quinn, Andrea Erichsen, Nathan Ruby, Emily Ruby, Cheryl Ruby, Jeff Magee, Elizabeth Vignola, Kyle Sills, Kristine Corneillie, Todd Corneillie, Chuck Dudley, Dale Morris, and Steve Fanner. Special acknowledgement goes to Chris Erichsen, who tirelessly and conscientiously performed the many tasks required to coordinate and implement this very complex monitoring program.

# STAKEHOLDERS ADVISORY GROUP PARTICIPANTS

The Stakeholders Advisory Group (SAG) was formed early in the project, and included representatives from local, regional, state and federal agencies and organizations. The group met five times and provided invaluable input into every key aspect of the project. This list identifies participants in SAG meetings.

- Armand Ruby, Larry Walker Associates (LWA) and Armand Ruby Consulting
- Brian Heiland, California Department of Water Resources (DWR)
- Betty Yee, Central Valley Regional Water Quality Control Board
- Casey Walsh Cady, Calif. Department of Food & Agriculture
- Chris Erichsen, LWA
- Christine Engel, City of Woodland
- Chuck Dudley, Dudley Ag
- Dave Feliz, California Department of Fish & Game, and Yolo Wildlife Area
- David Phillips, University of California, Davis
- Dawn Lindstrom, Putah Creek Council
- Denise Sagara, Yolo County Farm Bureau
- Doug Baxter, City of Woodland
- Jan Lowrey, Cache Creek Conservancy
- Janna Harren, California Department of Fish & Game
- Jim Beatty, City of Davis
- John Curry, Dixon Resource Conservation District
- John McNerny, City of Davis
- Kathryn Kuivila, US Geological Service
- Keith Smith, City of Davis
- Marianne Kirkland, DWR Division of Environmental Services
- Mike Hall, Conaway Ranch
- Mike Hardesty, Reclamation District 2068
- Paul Robins, Yolo County Resource Conservation District
- Petrea Marchand, Yolo County Planning Department
- Rich Marovich, Lower Putah Creek Coordinating Committee
- Rick Landon, Yolo County Agricultural Commissioner
- Robin Kulakow, Yolo Basin Foundation (YBF)
- Rollie Baxter, City of Woodland
- Stephen McCord, LWA
- Ted Sommer, DWR
- Tess Dunham, LWA

# INTRODUCTION

Historically, the Yolo Bypass area was a natural wetland with local groundwater seeping to the surface and draining southward to the Delta. Major storm events in the Sacramento Valley would flood the entire low-lying area surrounding the Sacramento River, creating what was referred to as an inland sea (Kelley, 1989). To gain control over the devastating floods, the Yolo Bypass was constructed in the 1930s as the centerpiece of the Sacramento River Flood Control Project, authorized initially by Congress in the Flood Control Act of 1917.

The northern beginning of the Bypass is the Fremont Weir. Water spills over the weir from the Sacramento River when flows in the river exceed approximately 70,000 cfs. The weir is located near the River's confluence with the Sutter Bypass, which at this point includes water from Sacramento Slough and Feather River. The smaller Sacramento Weir allows additional flood flows (i.e., only during the highest flows) to drain into the Bypass from the Sacramento and American Rivers near the confluence of those two rivers. Additional water is contributed from the Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek.

The Bypass is paralleled by the lower Sacramento River on its east side (separated by the City of West Sacramento) and is part of the counties of Yolo and Solano on the west side (Figure 1). In more than half of all water years<sup>1</sup>, the Bypass gets inundated. Water depths during flood discharges average 5-10 ft. Outside of flood discharge periods (i.e., for flows less than approximately 3,500 cubic feet per second (cfs)), water in the Bypass is conveyed entirely in the perennial eastern side channel referred to as Tule Canal north of I-80 and the Toe Drain south of I-80. The Toe Drain parallels the Sacramento River Deep Water Ship Channel.

Because of the control structures and frequent water management decisions, the Bypass watershed is a complex and ever-changing drainage area. During the dry season, the Bypass' main water sources are municipal wastewater and the west side tributaries of Cache and Putah Creeks. Diversions of irrigation return flows from the Colusa Basin Drain and the lower Sacramento River can also be significant. During the wet season, local and west side runoff is dwarfed by flood flows from the Sacramento, Feather, and American Rivers.

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<sup>1</sup> A water year, based on typical wet-dry season periods, is from October 1 to September 30.

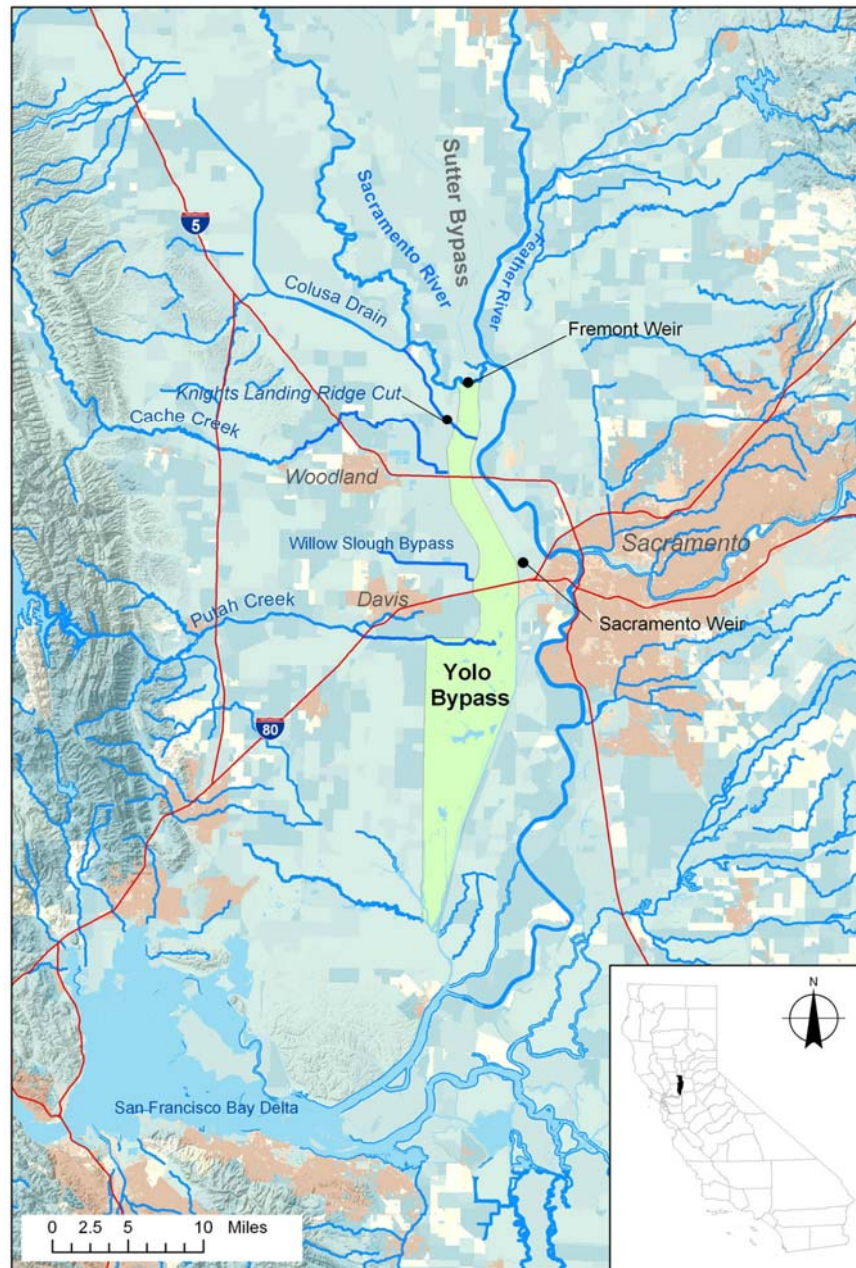
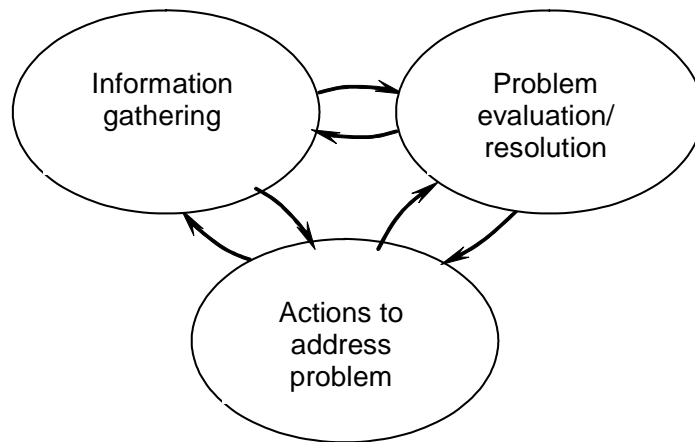


Figure 1. Location of the Yolo Bypass along with local urban areas and water bodies.

## Goals and Objectives of the Project

The objective of this project has been to develop a comprehensive water quality management plan for the Bypass. The development of this plan has followed the fundamental problem-solving approach depicted in Figure 2. The three inter-related elements – problem definition/evaluation, information gathering, and recommended actions – guided the development of this plan. Future activities recommended to implement this plan also follow this adaptive management framework.



**Figure 2. Basic elements of the planning process. The three interconnected elements form the framework for this document and a framework for adaptive management.**

The approach was framed in terms of the basic elements presented in Figure 2 and focused on the pollutants of concern (POCs).

Information gathering consisted of the following activities:

- Form an advisory group of Yolo Bypass stakeholders to participate in a collaborative process of developing this plan;
- Compile and evaluate existing water quality, flow, and land use information; and
- Identify the current water quality issues and POCs.

Problem evaluation/resolution consisted of the following activities:

- Conduct a surface water quality assessment and monitoring program to quantify the POCs and their apparent sources within the Bypass; and
- Assess whether the measured levels of POCs are causing impairment of beneficial uses in the Bypass.

Actions to address problems consisted of the following activities:

- Identify and evaluate alternative control measures for reducing POC concentrations and loads;
- For those POCs for which effective controls appear technically or economically infeasible, investigate applicability of current water quality objectives and, if appropriate, develop site-specific objectives, pollutant trading, or other alternative approaches;
- Provide public education and obtain public input regarding potential methods for improving water quality in the Bypass and reducing pollutant loads to the Delta; and

- Develop a Water Quality Management Plan report containing recommended implementation strategies to reduce POCs that are degrading beneficial uses in the Bypass.

The POCs identified by stakeholders and assessed in the monitoring program are listed later in this section. Potential controls for high and medium priority POCs are identified in the next section. The comprehensive water quality management plan is presented at the end of this report.

## Stakeholder Process

Stakeholder input and review was integral throughout the study and development of this plan. A Stakeholder Advisory Group was formed early in the project. This advisory group included representatives from public agencies, agriculture, and environmental advocates:

- Local municipalities – staff members from the cities of Davis and Woodland, University of California Davis (UC Davis) campus, and counties of Yolo and Solano, particularly those responsible for municipal wastewater treatment facilities and stormwater management programs;
- Agricultural interests – Yolo County Farm Bureau, Dixon Resource Conservation District, and Yolo County Agricultural Commissioner's office;
- Local environmental and resource conservation groups – Yolo Basin Foundation, Ducks Unlimited, Cache Creek Conservancy, Putah Creek Council;
- State agencies – Central Valley Regional Water Quality Control Board (CVRWQCB or Regional Board), California Department of Water Resources (DWR), State Water Resources Control Board (State Board), California Department of Health Services, California Department of Fish and Game; and
- Federal agencies – US Fish and Wildlife Service, US Environmental Protection Agency (USEPA) Region 9.

The Yolo Basin Foundation initiated the Yolo Bypass Working Group in 1998 under a CalFed Ecosystem Restoration Grant. This ad hoc stakeholder group has been very successful and continues to meet approximately every two months. Over 30 people representing a wide range of stakeholders with an interest in the Yolo Bypass regularly attend these meetings. Stakeholders that participated in this study informally represent a subset of the Yolo Bypass Working Group.

Stakeholder meetings covered the following topics:

1. 25 July 2003 – reviewed the project goals, objectives and approach; discussed water quality objectives applicable to the Bypass and potential list of POCs; discussed local hydrology and water management; identified proposed water quality monitoring sites, analytes and sampling frequency.
2. 15 October 2003 – discussed specific local hydrology and water management issues; discussed available monitoring data; agreed on list of POCs, monitoring sites, and sampling frequency;
3. 22 June 2004 – reviewed interim monitoring data; presentations by stakeholders: National Pollutant Discharge Elimination System (NPDES) permit compliance issues, wetland management and restoration issues, agricultural users' issues, Department of Water Resources' (DWR's) concerns and activities, and Regional Board concerns and priorities.

4. 3 December 2004 – reviewed project schedule; reviewed preliminary monitoring results; prioritized POCs; discussed potential control measures; discussed report outline.
5. 7 February 2005 – reviewed project schedule and remaining budget; identified feasible control measures by POC and discussed need to investigate site-specific objectives.

Minutes for these stakeholder meetings are included in Appendix 1.

## Identification of POCs

The stakeholder group developed a list of POCs based on current water quality concerns and interests for monitoring. The list of POCs and the rationale for their inclusion are as follows<sup>2</sup>:

- **Bacteria.** Total coliform, fecal coliform and *E. coli* are used by regulatory agencies as indicators of human pathogens. The presence of these constituents may also indicate contamination from domestic animals and wildlife. The presence of high levels of coliform and *E. coli* may indicate the presence of pathogens of human health concern in waters used for contact recreation. The presence of high levels of coliform and *E. coli* in irrigation water may also indicate the presences of pathogens that cause human health concerns in some food crops.
- **Boron.** Boron is an element commonly found in saline groundwater sources. It has properties that are somewhat like metals. The major source locally is leaching from soil and extraction in groundwater. High concentrations of boron can stress rice and other irrigated crops.
- **Metals.** Aluminum, mercury, and selenium have been detected in the Bypass at levels in excess of water quality standards. Copper, chromium(III), and lead have also been detected. Some metals, such as aluminum and selenium, tend to be from natural sources. Mercury was mined extensively in the Cache and Putah Creek watersheds prior to any environmental regulations. Wetlands tend to enhance the methylation process that drives bioaccumulation. Other metals tend to come from urban runoff and municipal wastewater discharges. Most metals are a concern for toxicity to aquatic organisms. Mercury and selenium are potent neurotoxins of concern to humans and wildlife.
- **Nitrate.** Nitrate is a concern for human health and eutrophication. It is often present at elevated levels in municipal wastewater discharges, agricultural irrigation tailwater, and urban runoff.
- **Organic Carbon.** Organic carbon in water increases productivity of aquatic ecosystems but is detrimental to drinking water supplies. The presence of high levels of organic carbon in drinking water requires drinking water providers to increase the chlorination process in order for drinking water to meet appropriate standards when delivered to consumers. However, the chlorination process creates harmful disinfection by-products known as trihalomethanes. Trihalomethanes are considered to be carcinogenic.
- **Pesticides.** Carbamate, organochlorine, and organophosphate based pesticides have been detected in Bypass water by existing water monitoring programs. The presence of these pesticides above threshold concentrations can cause negative impacts on aquatic life within the Bypass. Common sources of such pesticides, such as agricultural and urban runoff, exist in the watershed.

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<sup>2</sup> This list was reorganized slightly from the original list to facilitate grouping the analyses presented subsequently.

- **Salinity.** High salts content in water potentially impacts productivity of agricultural crops and may create problems for municipal uses. Local groundwater aquifers, the principal water supply source for the Cities of Davis and Woodland and UC Davis campus, are relatively high in salts content. Urban water uses, particularly the use of water softeners, increase salts content in wastewater discharges. Irrigation practices that enhance evaporation and leaching also increase salt content of irrigation return flows.
- **Total Suspended Solids (TSS).** TSS is often used as a standard indicator of erosion and sediment transport. Many POCs are strongly associated with particulates measured as TSS.

In addition to standard field measurements of temperature and pH, the following were also determined to be of interest for monitoring:

- **Chronic Toxicity.** Testing for chronic toxicity was conducted for water column and sediment samples to directly measure the presence of aquatic toxicity. The testing involves exposing selected organisms to receiving water samples for a period of 96 hours to 7 days, depending on the species. The species most commonly selected for freshwater toxicity tests include a cladoceran (*Ceriodaphnia dubia*), fathead minnows, and algae (*Selenastrum capricornutum*). Toxicity is defined as a statistically significant difference in effects such as growth rate.
- **Sediment.** Sediment samples were also collected and analyzed for metals, pesticides, and TOC.
- **Color.** Color is a potential indicator of effects of agricultural runoff.
- **Hardness.** Hardness affects toxicity for metals, with lower hardness increasing metals toxicity.

### Support for CalFed Watershed Program and Coordination with Other Programs

This plan is related in purpose with several other efforts within the Yolo Bypass watershed. The most relevant efforts, described in the final section of this report, include:

- California Drinking Water Policy,
- Yolo County Integrated Water Resources Management Plan,
- Cache Creek Resources Management Plan,
- Willow Slough Watershed Resources Management Plan, and
- Yolo Bypass Wildlife Area Management Plan.

## Regulatory Framework

The regulatory framework described in this section identifies the major regulations with which any actions would have to comply.

### Basin Plan Beneficial Uses

Beneficial uses of water in the Yolo Bypass are legally designated in the Basin Plan (CVRWQCB, 1998). Beneficial use designations determine the applicable water quality objectives. In addition to the beneficial uses for the Yolo Bypass, there are additional and different beneficial uses for the water bodies in and near the Bypass such as Cache Creek, Putah Creek and the Delta. Consequently these additional beneficial

uses should also be considered. Between these water bodies, almost every beneficial use designation applies. The various beneficial uses include:

- Agricultural Supply (AGR) – Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing.
- Water Contact Recreation (REC-1) – Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.
- Non-contact Water Recreation (REC-2) – Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
- Warm Freshwater Habitat (WARM) – Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
- Cold Freshwater Habitat (COLD) – Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
- Spawning, Reproduction, and/or Early Development (SPWN) – Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
- Wildlife Habitat (WILD) – Uses of water that support terrestrial or wetland ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

An additional beneficial use, Municipal and Domestic Supply (MUN) does not apply to the Bypass but does apply to Cache Creek and Putah Creek upstream and to the Delta downstream.

### **Most Restrictive Potentially Applicable Water Quality Criteria**

Water quality objectives are defined by the California Water Code<sup>3</sup> as “the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.” Such objectives are to be adopted into the Basin Plan to protect reasonable beneficial uses after considering a number of factors. The Basin Plan currently contains some numeric water quality objectives for the POCs addressed in this report. However, many of the applicable objectives are in the narrative format. When objectives are narrative, the Regional Board has established a practice of interpreting the narrative objectives with available water quality criteria from a variety of sources. The actual criteria used by the Regional Board when interpreting narrative objectives may vary on a case-by-case basis. As a result, it is difficult to accurately predict what criteria may be applicable to the POCs. In order to compare the monitoring results with some baseline water quality

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<sup>3</sup> See CA Water Code §13050.

indicator, this report utilizes the most potentially restrictive criteria available to determine if a POC is a concern with regard to maintaining water quality standards. The criteria used herein are for comparison and baseline purposes only and may or may not be used by the Regional Board in a regulatory permitting context. The most restrictive potentially applicable criteria for the various POCs are provided here.

### *Bacteria*

The beneficial use most in need of protection from bacteria is Water Contact Recreation (REC-1). The Basin Plan specifies that the fecal coliform geometric mean of at least five samples for any 30-day period shall not exceed 200 Most Probable Number per 100 mL (MPN/100mL), nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 mL. A proposed Basin Plan amendment requires that "In waters designated for contact recreation (REC-1), the *E. coli* concentration, based on a minimum of not less than five samples equally spaced over a 30-day period, shall not exceed a geometric mean of 126 MPN/100 mL and shall not exceed 235 MPN /100 mL in any single sample.

### *Boron*

The United Nations Recommended Agricultural Water Quality Goals for total boron is 700 ug/L for the most sensitive crops (Ayers and Westcot, 1985). Agricultural Water Quality Criteria contained in the United Nations are not adopted water quality objectives contained in the Basin Plan. However, the Regional Board has used the recommended goals contained in the United Nations Report to interpretative narrative objectives contained in the Basin Plan.

### *Metals*

#### Aluminum

The USEPA National Recommended Ambient Water Quality Chronic Aquatic Life Criterion for total aluminum concentration is 87 ug/L and the recommended acute criterion is 750 ug/L. There is no criterion for dissolved aluminum. The recommended chronic criteria of 87 ug/l is qualified and is considered to apply mostly to waters that are low in pH (6.5-6.6) and low in hardness (< 10 mg/l). The average pH and hardness for the in-Bypass monitoring sites was 8.0 and 223 mg/L, respectively.

#### Chromium

Based on an average hardness in the Bypass of 220 mg/L, the California Toxics Rule (CTR) criterion for dissolved chromium (III) in freshwater is 340 ug/L as a continuous (four-day average) concentration. The CTR reference value for total chromium (III) is 395 ug/L.

#### Copper

Based on an average hardness in the Bypass of 220 mg/L, the CTR criterion for dissolved copper in freshwater is 17.6 ug/L as a continuous (four-day average) concentration. The CTR reference value for total copper is 18.3 ug/L.

#### Lead

Based on an average hardness in the Bypass of 220 mg/L, the CTR criterion for dissolved lead in freshwater is 5.9 ug/L as a continuous (four-day average) concentration. The CTR reference value for total lead is 8.68 ug/L.

#### Mercury

The CTR has a total mercury criterion of 51 ng/L as a monthly average, intended to be protective for consumption of organisms. There is no CTR criterion for methylmercury, although the Cache Creek mercury Total Maximum Daily Load (TMDL) has proposed a water quality objective of 0.06 ng/L.

### Selenium

The CTR criterion for total selenium is 5.0 ug/L as a continuous (four-day average) concentration in freshwater.

### Nitrate

While there is no nitrate objective applicable to the Bypass, the USEPA Ambient water quality criterion is 10 mg-N/L<sup>(4)</sup>. Local site conditions, particularly the availability of other nutrients for algal growth, play an important role in determining actual effects of elevated nitrate concentrations.

### Organic Carbon

There are no recognized standards for TOC or DOC in surface waters. For drinking water, lower organic carbon concentrations are better, regardless of the magnitude.

### Pesticides

The lowest potentially applicable criteria for detected pesticides are shown in Table 1. These values were obtained from CVRWQCB (2003). Quite commonly, applicable criteria for pesticides are below the analytical detection limit. The evaluation in this report of water quality issues related to pesticides focuses on detected compounds.

**Table 1. Potentially applicable water quality criteria used to evaluate monitoring data.**

Pesticide	Criteria (ug/L)	Source
Diuron	10	Drinking Water Health Advisory or Suggested No Adverse Response Level for toxicity other than cancer risk
Methomyl	0.52	USEPA National Recommended Ambient Water Quality Criterion
4,4'-DDE	0.00059	California Toxics Rule for consumption of aquatic organisms
Diazinon	0.1	USEPA draft recommended criteria
Chlorpyrifos	0.009	Derived by the California Department of Fish and Game; not a national recommended criterion.

### Salinity

The United Nations agricultural goals for salt-sensitive crops in arid areas include, but are not limited to, 106 mg/L chloride, 700 umhos/cm specific conductance, and 450 mg/L total dissolved solids. The Regional Board has utilized these goals as six-month or annual averages in recent NPDES permits. The State Board has recently determined that the UN criteria may need to be adjusted to site-specific conditions, including climate (SWRCB Order No. WQO-2004-0010).

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<sup>4</sup> The units are given as mg of *nitrogen (N)* per liter.

## List of Impaired Waters and TMDL Status

Under Section 303(d) of the 1972 Clean Water Act, states, territories and authorized tribes are required to develop a list of water quality limited segments. These waters on the list do not meet water quality standards, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that the state establish priority rankings for water on the lists and establish pollutant loads for the various sources called Total Maximum Daily Loads (TMDLs). TMDL implementation plans are legally enforceable once adopted in the Basin Plan.

The 2002 state-wide listing of impaired waters, referred to as the "303(d) list", was approved by USEPA on July 25, 2003. Direct tributaries upstream and the Delta downstream are listed as impaired as indicated in Table 2. The Yolo Bypass is not listed as impaired. However, TMDLs are in various stages of development and implementation for water bodies both upstream and downstream of the Yolo Bypass.

## NPDES Permits

The National Pollutant Discharge Elimination System (NPDES) permit program was established under Section 402 of the CWA, which prohibits the unauthorized discharge of pollutants from a point source (pipe, ditch, well, etc.) to waters of the U.S., including municipal, commercial, and industrial wastewater discharges and discharges from large animal feeding operations. Permittees must verify compliance with permit requirements by monitoring their effluent, maintaining records, and filing periodic reports. Different types of discharges to waters of the State are permitted through various NPDES permit programs. The following permit programs are relevant within the local Yolo Bypass watershed:

- Construction storm water runoff – Construction sites disturbing one acre or more of land are required to comply with a statewide general permit. The permit prohibits the discharge of any pollutants from construction sites and requires Storm Water Pollution Protection Plans (SWPPPs) for all permitted sites.
- Industrial storm water runoff – Industrial facilities meeting certain criteria for size and potential pollutants on site are required to comply with a statewide general permit. The permit prohibits the discharge of any pollutants from the property and requires SWPPPs for all permitted sites.
- Stormwater – Municipalities and non-traditional entities meeting certain population size, growth criteria, location, or pollution potential are required to comply with a permit for the discharge of storm water to waters of the State. Elements required for each entity's stormwater management program include: Public Education and Outreach, Public Involvement and Participation, Illicit Discharges, Construction Activities, New Development and Redevelopment, and Municipal Operations.
- Wastewater – Municipal, commercial, and industrial wastewater discharges, and discharges from large animal feeding operations are regulated by the NPDES permit program. Individual permits are granted with conditions and limits on the effluent water quality. Discharges of municipal and industrial wastewater to land are regulated through state Waste Discharge Requirements.

Specific permittees regulated by these permit programs are described next in the Environmental Setting section.

**Table 2. 2002 303(d) list of impaired waters associated with the Yolo Bypass and status of TMDLs.**

<b>Water Body</b>	<b>Pollutant / Stressor</b>	<b>Priority</b>	<b>Potential Source(s)</b>	<b>TMDL Status</b>
Sacramento River (Red Bluff to Knights Landing)	Unknown toxicity	Low	Unknown	No activity
Feather River (Lake Oroville Dam to Confluence with Sacramento River)	Diazinon	High	Agriculture, Urban Runoff/Storm Sewers	Adopted
	Group A Pesticides	Low	Agriculture	No activity
	Mercury	Medium	Resource extraction	No activity
	Unknown toxicity	Low	Unknown	No activity
Sutter Bypass	Diazinon	Medium	Agriculture	Adopted
Colusa Basin Drain	Azinphos-methyl	Medium	Agriculture	No activity
	Carbofuran/Furadan	Low	Agriculture	No activity
	Diazinon	Medium	Agriculture	Adopted
	Group A Pesticides	Low	Agriculture	No activity
	Malathion	Low	Agriculture	No activity
	Methyl Parathion	Low	Agriculture	No activity
	Molinate/Odram	Low	Agriculture – irrigation tailwater	No activity
	Unknown Toxicity	Low	Agriculture	No activity
Clear Lake	Mercury	High	Resource extraction	Adopted
	Nutrients	Medium	Unknown	Draft Technical Report completed
Sulphur Creek	Mercury	Medium	Resource extraction	2 <sup>nd</sup> draft staff completed
Harley Gulch	Mercury	Medium	Resource extraction	2 <sup>nd</sup> draft staff completed
Cache Creek	Mercury	Medium	Resource extraction	2 <sup>nd</sup> draft staff completed
	Unknown toxicity	Low	Unknown	No activity
Lake Berryessa	Mercury	Low	Resource extraction	No activity
Lower Putah Creek	Mercury	Low	Resource extraction	No activity
Delta (eastern portion)	Mercury	Medium	Resource extraction	Draft staff report in progress
	Unknown toxicity	Low	Unknown	No activity
	Chlorpyrifos and Diazinon	High	Agriculture, Urban Runoff/Storm Sewers	Draft staff report in progress
	DDT	Low	Agriculture	No activity
	Group A pesticides	Low	Agriculture	No activity

### Waivers from Waste Discharge Requirements

Irrigation return flows and stormwater runoff from agricultural fields is not regulated under the federal NPDES permit program like the other types of discharges described above. Instead, agricultural sources of nonpoint source pollution are subject to state water quality requirements stemming from California's Porter-

Cologne Water Quality Control Act. Under Porter-Cologne<sup>5</sup>, all potential discharges of waste into waters of the state are required to file a report of waste discharge and obtain waste discharge requirement, unless waived by the State or Regional Board. The CVRWQCB adopted a *Conditional Waiver for Irrigated Agriculture* in July of 2003. Under the *Conditional Waiver*, farmers with irrigation return flows and stormwater runoff from irrigated agricultural lands are not required to submit a report of waste discharge and obtain waste discharge requirements. However, in lieu of such requirements, growers are required to comply with the conditions of the waiver, which includes extensive monitoring requirements and the establishment of water quality management plans if required by the Regional Board. The *Conditional Waiver* also encourages growers to utilize management practices for the protection of water quality in their agricultural operations.

#### **404 Corps of Engineer Permits**

In addition to the NPDES permit provisions described above, section 404 of the federal CWA requires individuals and public agencies to obtain a permit before discharging any dredge or fill into a water of the United States. Such permits are administered by the Secretary of the Army through the Chief Engineer at the Army Corps of Engineers. Since the Yolo Bypass is considered a water of the U.S., some of the identified control actions may require that a section 404 permit be obtained before being implemented.

A water quality certification is required from the Regional Board if a 404 permit is needed. In cases where the Army Corps of Engineers does not have jurisdiction (e.g., isolated wetlands), the Regional Board can still issue a water quality certification.

#### **Streambed Alteration Agreements (California Fish and Game Code 1600 et seq.)**

Besides needing to obtain a section 404 permit, some of the identified control actions may require that a streambed alteration agreement be obtained from the California Department of Fish and Game. Streambed alteration agreements are required if a project may in any way alter a streambed or obstruct or divert the flow of a natural waterway.

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<sup>5</sup> See CA Water Code §13000 et seq.

# ENVIRONMENTAL SETTING

This section describes the environmental setting driving the current water quality conditions in the Bypass.

## Hydrology and Water Resources Management

Hydrology of the Yolo Bypass is affected by both local and distant conditions related to hydraulic control structures, water management decisions, and weather patterns. Hydrology and water management within the Bypass is summarized by season and Bypass segment in Table 3. A more detailed description of the Bypass hydrology on a monthly time scale is provided in draft form in Appendix 2<sup>6</sup>.

**Table 3. Basic hydrology of the Yolo Bypass.**

Bypass Zone	Fall (September – December)	Wet Season (January – March)	Dry Season (April – August)
Upper (North of I-80)	Effluent from cities of Davis and Woodland; Knights Landing Ridge Cut water supplied to some irrigated fields; Conaway Ranch water supplied from Sacramento River	Effluent and pulses of stormwater runoff from cities of Davis, Woodland and the portion of West Sacramento north of I-80; increased flows from Knights Landing Ridge Cut, Cache Creek and Willow Slough;	Effluent from cities of Davis and Woodland utilized locally; Cache Creek flows and City of Woodland storm drains diverted to Conaway Ranch; irrigation tailwaters pumped back onto downstream fields
Transition (I-80 to Putah Creek)	Tidal prism extends up through this zone	Pulses of stormwater runoff from southern portion of City of Davis	Putah Creek water utilized in Yolo Basin Wildlife Area; tidal prism extends up through this zone; pumped irrigation water recycled or from Delta
Southern (South of Putah Creek)	Putah Creek “conservation releases” pulse plus UC Davis effluent	UCD effluent and pulses of stormwater runoff from UC Davis and; tidal prism restricted to this zone	Effluent from UC Davis; some water pumped out of Bypass; some land used for pasture
Bypass-wide	Rice fields drained; principal water use for flooding duck clubs, wildlife habitat and rice paddies (for straw decomposition)	Rainfall runoff from fields in and adjacent to Bypass; principal water use for flooding duck clubs, wildlife habitat and rice paddies (for straw decomposition); potential extreme flows from Sacramento River over Fremont Weir	Wildlife habitat reduced to brood ponds; farmland prepared, planted, irrigated, and harvested

<sup>6</sup> Description courtesy of Chuck Dudley.

As an alternative to the seasonal hydrologic calendar framing the discussion in Table 3, the annual hydrology for the Bypass can be described in terms of discharge:

- Dry (Irrigation) Season: Major sources of water include effluent from the municipal wastewater treatment plants (POTWs) of the Cities of Woodland and Davis and the UC Davis campus, imported Sacramento River water (for irrigation purposes), and water from the Toe Drain that is pumped onto agricultural fields for irrigation and to wildlife habitat. Low flows from Putah Creek, Willow Slough, Cache Creek, and Knight's Landing Ridge Cut also contribute. Agricultural tailwater is largely recycled
- Wet Season: Pulses of urban stormwater runoff combine with POTW effluent and higher flows in creeks to provide the primary sources of water within the Bypass. The available water created during the wet season is often used to flood public and private lands for duck clubs, wildlife habitat and the break-down of rice stubble remaining on rice fields after harvest.
- Flooded: Flood flows in the Bypass come from the Feather River and upper Sacramento River watersheds via the Fremont Weir at the northern end of the Bypass, from the American River via the Sacramento Weir along the east side of the Bypass, and from local creeks. These flood flows drastically alter what would be considered "average" conditions. It is not uncommon for flood flows to exceed 150,000 cfs in the Bypass during wet years, as compared to 20,000 cfs in Cache Creek, and 20 cfs combined POTW effluent. The basic surface water flow paths and maximum flow capacities in the Bypass are shown pictorially in Appendix 3.

Additional discussion of hydrology in the Bypass is provided by the Yolo Bypass Working Group et al. (2001).

### Major Tributaries to the Yolo Bypass

The northern beginning of the Bypass is the Fremont Weir, located approximately 2 miles upstream of the town of Verona (see Figure 1 above and Figure 5 below). Water spills over the weir from the Sacramento River when flows in the river exceed approximately 70,000 cfs. Verona is at the confluence with the Feather River and Sutter Bypass<sup>7</sup>. Over ten times more water spilling over Fremont Weir may come from the Sutter Bypass than from the Sacramento River. By this mechanism, the Bypass relieves pressure on the main levee system along the river channel and helps keep flows within the channel's design capacity. The smaller Sacramento Weir, located approximately 3 miles upstream of the American River, allows additional flood flows (i.e., only during the highest flows) to drain into the Bypass from the Sacramento and American Rivers. The Fremont Weir is a fixed-crest overflow weir, thus flow into the Bypass is uncontrolled. On the other hand, the Sacramento Weir is gated, thereby controlling flow into the Bypass via the lateral Sacramento Bypass.

The Colusa Basin Drain (Drain) watershed comprises nearly 1,620 square miles in the Sacramento Valley, and includes portions of Glenn, Colusa, and Yolo counties. There are 32 ephemeral streams that convey storm runoff to the Drain. The Drain is an artificial channel designed to convey irrigation drainage to the Knights Landing outfall gates for discharge into the Sacramento River. When the water level in the river exceeds the water level in the Drain, Drain water discharges into the Knights Landing Ridge Cut directly into the Yolo Bypass. The Knights Landing Ridge Cut, which consists of two excavated channels with a

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<sup>7</sup> The Feather River floods into the Sutter Bypass upstream of this point.

center island, has a discharge capacity of approximately 20,000 cfs. Water from the Drain is pumped into the Ridge Cut for irrigation at other times of the year, providing additional water into the upper Bypass during the summer-fall period.

Clear Lake and Indian Valley Reservoir each store approximately 300,000 acre-feet of water in the Cache Creek watershed. This water is delivered through Capay Valley but diverted at the Capay Dam for irrigation. During the dry season, Cache Creek downstream of Capay Dam is either dry or contains some groundwater ex-filtration and irrigation tailwater. Because of the different hydrologic conditions and water management, Cache Creek is often described in terms of an upper watershed upstream of Capay Dam and a lower watershed downstream of Capay Dam. Cache Creek discharges into the Bypass through the Cache Creek Settling Basin, an integral component of the Yolo Bypass flood control project. The basin directs water from Cache Creek into the Bypass through a low-flow channel passing on the west and south side of the basin area. When the low-flow culvert's discharge capacity is exceeded (approximately 400 cfs), the basin begins to fill. When the outlet weir height is reached, water spills over the weir into the Bypass. By reducing the sediment load from this highly erosive watershed, flood conveyance capacity is maintained in the Bypass. Nonetheless, a sediment fan is observable directly east of the basin, in the Bypass.

The Willow Slough watershed drains most of the central part of Yolo County between Cache Creek and Putah Creek. Because of natural levees that formed through deposition of sediment along the valley floor, local runoff flows *away* from the main Cache Creek and Putah Creek channels and enters a complex network of sloughs and small drainage channels that flow eastward and eventually consolidate into Willow Slough before discharging into the Yolo Bypass. Landowners have realigned and reconfigured many of the sloughs to accommodate agricultural activities. Runoff has undoubtedly been accelerated by grazing in the upper watershed and foothills areas and widespread land leveling and prebedding of fields in the valley floor area. East of State Highway 113, the northeast-trending natural channel of Willow Slough has been blocked off and replaced with a flood bypass channel, the Willow Slough Bypass, which flows directly east to the western edge of the Yolo Bypass. Water in the Slough during the dry season is entirely irrigation tailwater and field drainage and is used so efficiently that essentially none of this water reaches the Bypass.

The Monticello Dam on Putah Creek stores water in Lake Berryessa from a 576-square-mile drainage basin to the northwest of Solano County on the eastern slope of the Coast Range in Napa and Lake Counties<sup>8</sup>. Lake Berryessa has a storage capacity of 1,602,000 acre-feet. The water is released during the irrigation season and diverted into the 30-mile-long Putah South Canal. In addition to providing irrigation water, the canal conveys municipal and industrial water for Vacaville, Fairfield, Suisun, and Vallejo, as well as neighboring military installations. Although the majority of runoff from the Putah Creek watershed is diverted out of the Yolo Bypass watershed, 16-46 cfs is maintained through the Putah Diversion Dam at Lake Solano. The monthly non-diverted flow rate schedule was set in a settlement agreement<sup>9</sup>.

The UC Davis Arboretum Waterway is a 100-acre constructed stormwater retention basin created in the 1960s along a portion of the historic channel of the North Fork of Putah Creek. All stormwater runoff from the central campus is routed into the Arboretum Waterway. Water collected in the channel largely infiltrates into the local aquifer. During a storm event, water from the Arboretum Waterway spills over a weir at the west end and large pumps send the water via pipeline into the South Fork of Putah Creek. The South Fork from the UC Davis campus to the Bypass is an engineered channel designed to convey flood flows.

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<sup>8</sup> More information on the Solano Project can be found at <http://www.usbr.gov/dataweb/html/solano.html>.

<sup>9</sup> The settlement agreement can be viewed on-line at <http://www.putahcreek.org/Settlement%20Agreement.htm>.

## Permitted Wastewater Dischargers

The permitted municipal wastewater treatment facilities in the watershed discharge as indicated here.

- City of Woodland – The secondary treatment facility discharges 6.8 million gallons per day (MGD) into Tule Canal.
- City of Davis – The secondary treatment facility with overland flow discharges approximately 6 MGD. Generally during the February-June period, effluent is discharged into a 400-acre wildlife habitat wetland and pumped from there into a drain on the west side of the Bypass at the mouth of Willow Slough Bypass. At other times effluent is discharged directly into Willow Slough Bypass.
- UC Davis campus – The advanced (tertiary) treatment facility with ultraviolet disinfection discharges 2.5 MGD into Putah Creek. The outfall is located by Old Davis Road south of the campus.

The City of Winters operates a grassland irrigation system that does not discharge to surface waters. Similarly, the City of Esparto operates a primary treatment facility with evaporation/percolation ponds that do not discharge to surface waters. Effluent from the City of West Sacramento is discharged into the lower Sacramento River. Facilities upstream of Clear Lake are not addressed. Industrial facilities discharge into municipal sewer service lines rather than directly into surface waters.

## Permitted Stormwater Dischargers

Recently, larger urbanized areas within the Cache and Putah Creeks watersheds have been regulated under a statewide general permit for the discharge of water from municipal stormwater systems. These areas include:

- City of Woodland – Discharging into lower Cache Creek and the Bypass;
- City of West Sacramento – Discharging into the Yolo Bypass for most of the City;
- City of Davis – Discharging into Willow Slough Bypass and the Bypass. Some stormwater is diverted into the wildlife wetlands;
- County of Yolo, El Macero and Willowbank residential communities adjacent to South Davis – Discharging into the South Davis Drainage Ditch which is pumped into the Bypass; and
- UC Davis campus – Discharging into lower Putah Creek just upstream of the municipal wastewater treatment facility's outfall.

## Agricultural Irrigation

Local farmers irrigate their land with both surface water and groundwater. Within the Bypass, water is pumped from the Sacramento River to some areas, while serendipitous flows in canals are also pumped onto fields within and adjacent to the Bypass. Irrigation tailwater and rainfall runoff flow back to the network of canals that lead into the Bypass and generally south-eastward towards the main in-Bypass drain, Tule Canal and the Toe Drain.

## **Water Withdrawals from the Bypass**

The North Bay Aqueduct withdraws water out of Cache Slough at the southern end of the Bypass and delivers it through 27 miles of underground pipelines and two pumping plants to water users in Napa and Solano counties.

The communities west of the Bypass rely exclusively on local groundwater aquifers for potable water. Water supply for the City of West Sacramento comes from the Sacramento River.

## **Land Uses**

Land uses are described for the Bypass' local watershed (i.e., not including the Sacramento and Feather Rivers watersheds) and for the Yolo Bypass proper.

### **Land Uses in the Yolo Bypass Watershed**

Major land uses within the watersheds of the west-side tributaries are portrayed in Figure 3, and quantified in Table 4 which includes the Feather and upper Sacramento River watersheds. Agriculture, forest, and rangeland are the dominate land uses in the Bypass' watershed.

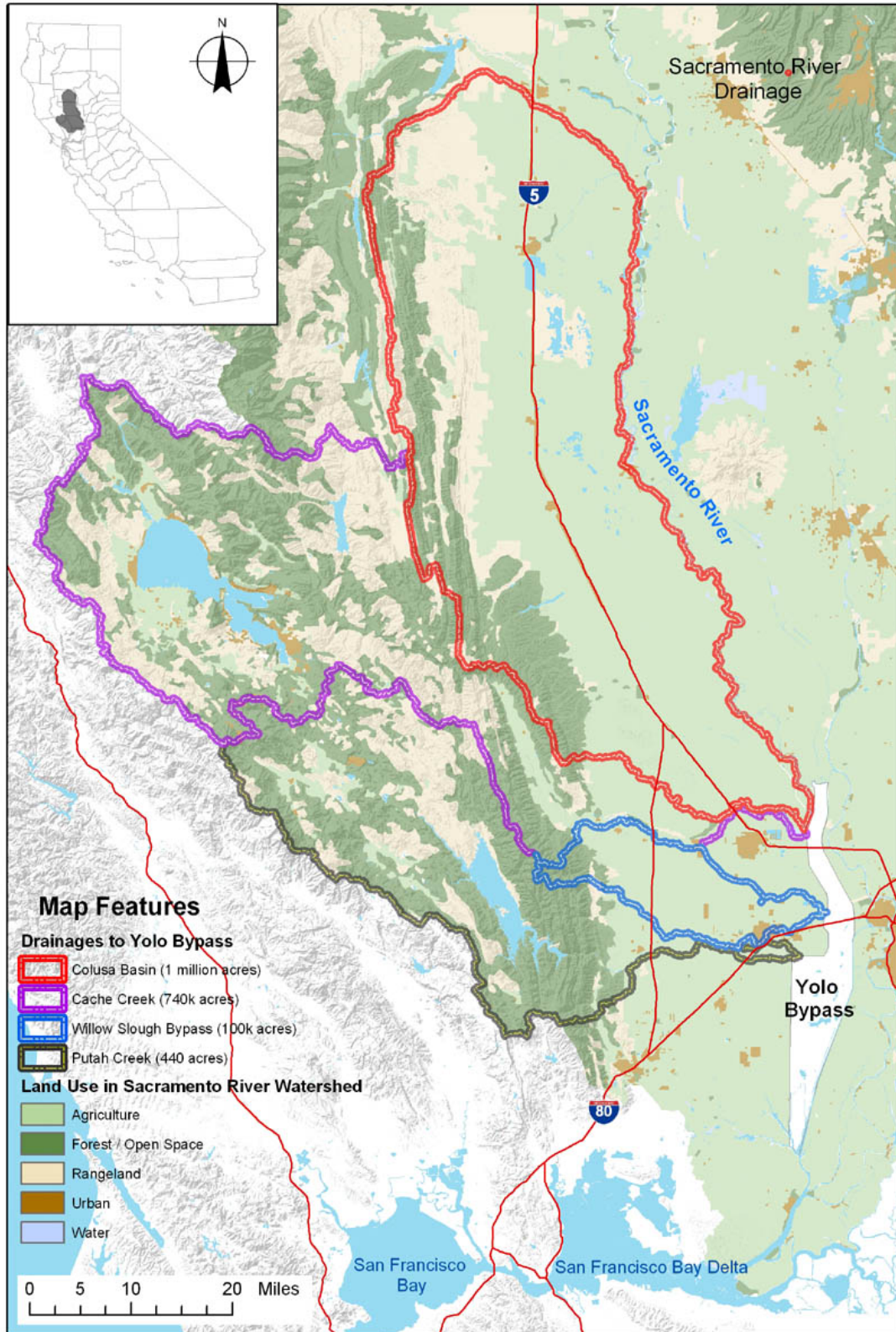


Figure 3. General land use in the upstream watersheds of the Yolo Bypass, not including the Feather River or upper Sacramento River watersheds.

Table 4. Land use summary of watersheds contributing to the Yolo Bypass.

<b>Watershed</b>	<b>Land Use</b>	<b>Land Use Acres</b>	<b>Percent of Watershed</b>
<b><i>Willow Slough Bypass</i></b>	<b><i>Total Acres</i></b>	<b><i>102,893</i></b>	
	Agriculture	85,843	83.4
	Forest	10,990	10.7
	Residential	4,451	4.3
	Rangeland	1,343	1.3
	Water	151	0.1
	Transitional Areas	114	0.1
<b><i>Putah Creek</i></b>	<b><i>Total Acres</i></b>	<b><i>435,777</i></b>	
	Forest	258,769	59.4
	Rangeland	106,003	24.3
	Agriculture	47,166	10.8
	Water	18,137	4.2
	Transitional Areas	3,027	0.7
	Residential	2,675	0.6
<b><i>Cache Creek</i></b>	<b><i>Total Acres</i></b>	<b><i>737,697</i></b>	
	Forest	337,775	45.8
	Rangeland	242,624	32.9
	Agriculture	102,253	13.9
	Water	38,783	5.3
	Residential	13,411	1.8
	Transitional Areas	2,298	0.3
	Wetlands	555	0.1
<b><i>Colusa Basin</i></b>	<b><i>Total Acres</i></b>	<b><i>1,030,498</i></b>	
	Agriculture	664,204	64.5
	Rangeland	182,997	17.8
	Forest	167,532	16.3
	Residential	13,866	1.3
	Transitional Areas	819	0.1
	Wetlands	558	0.1
	Water	523	0.1
<b><i>Sacramento / Feather Rivers</i></b>	<b><i>Total Acres</i></b>	<b><i>12,588,890</i></b>	
	Forest	8,425,556	66.9
	Rangeland	2,249,455	17.9
	Agriculture	1,364,087	10.8
	Water	218,740	1.7
	Residential	135,477	1.1
	Transitional Areas	105,402	0.8
	Wetlands	83,877	0.7
	Perennial Snowfields	5,733	0.05
	Shrub and Brush Tundra	561	0.005

Source: USGS, 1994. GIRAS Land use / Land cover data for the Conterminous United States by quadrangles at scale 1:250,000

## Land Uses in the Yolo Bypass

Land use within the Bypass is restricted by flood easements held by the Sacramento-San Joaquin Drainage District. These easements do allow for the use of the land within the Bypass for duck clubs and agriculture. The primary seasonal crops are rice, safflower, tomatoes, corn and other grains. Farming activity is concentrated in spring (following any wet season flooding) and summer. Seasonal uses in the Bypass are portrayed in Figure 4.

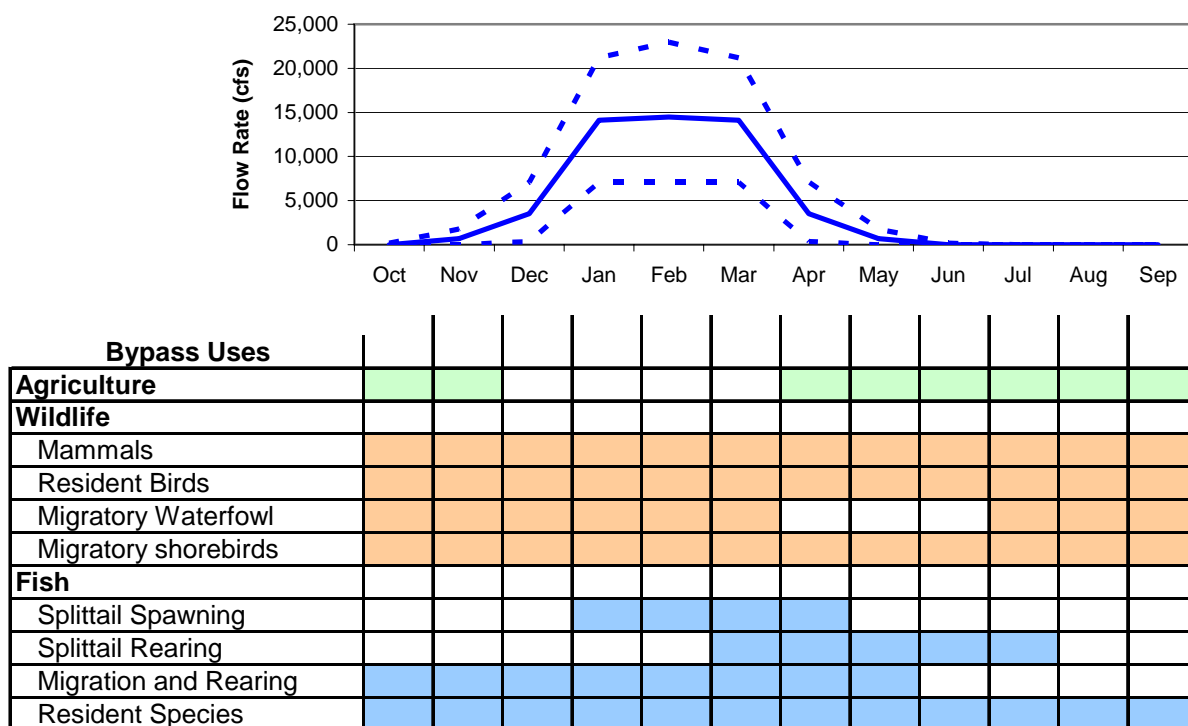


Figure 4. Seasonal uses of the Yolo Bypass (Sommer et al., 2001). The flow rates presented in the graph at top represent normal (solid line) and extreme (upper and lower dashed lines) years.

Approximately one-third of the Bypass is a mosaic of ponds and other uncultivated areas. The largest of these is the Yolo Bypass Wildlife Area, encompassing over 16,000 acres around I-80. The Bypass is a critical link on the Pacific Flyway bird migration corridor. Its waterways supply valuable aquatic habitat to several fish species. Land uses in the Bypass are described in greater detail by the Yolo Bypass Working Group et al. (2001).

Current and potential future recreational uses of water in the Bypass, generally in order of more popular first, include: bank fishing, recreational boating. Some have identified swimming as a recreational use of the Bypass; however, surveys have not been able to document any swimming activities. Hunting, although limited to certain seasons and locations, is also popular. Other outdoor recreational activities include wildlife viewing, hiking/walking, biking, photography, and sunbathing (Jones & Stokes and LWA, 2000).

# MONITORING PROGRAM

The monitoring program was designed to characterize major source waters to the Bypass along with in-Bypass processes. The program spanned a full water year to characterize seasonal variability. Monitoring was based on individual “grab” samples collected on a monthly basis from local surface waters, with analysis for chemical constituents and aquatic toxicity testing on a subset of samples. Limited toxicity testing and chemical analyses of streambed sediments were also performed. This section describes the monitoring program. Subsequent sections summarize and assess the monitoring results, leading to a prioritization of the POCs.

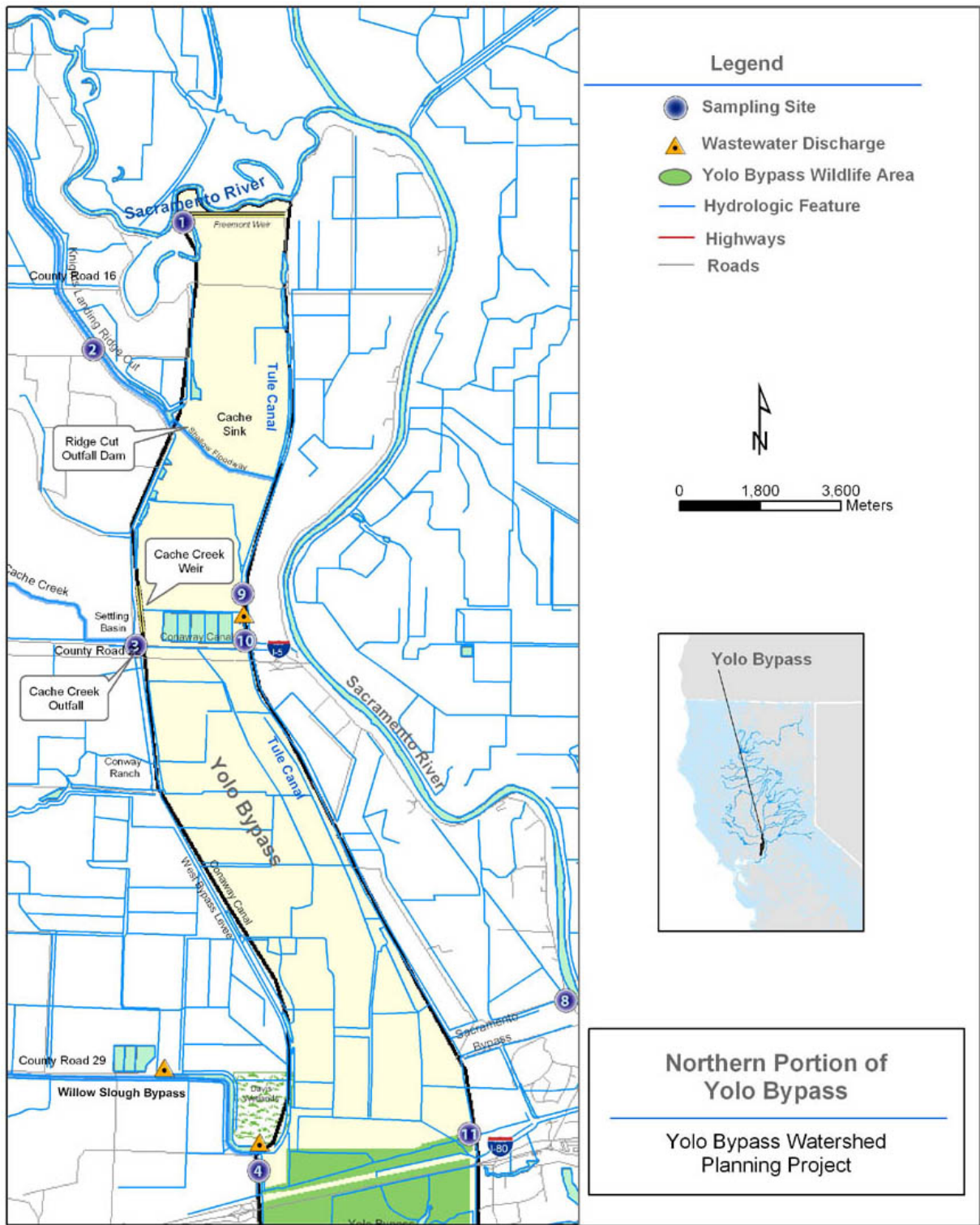
## Description of Monitoring Stations

The monitoring program included monitoring at 12 locations in the Yolo Bypass. Eight sites are located at outfalls of major channels or creeks (inputs) flowing into the Bypass, including two sites at flood weirs. Four sites are located along the perennial channel, Tule Canal and the Toe Drain. The Yolo Bypass Wildlife Area (YBWA) site represents water pumped up from the Toe Drain, not in or drained from the YBWA. The Yolo Bypass monitoring sites are listed in Table 5 and illustrated in Figure 5. Photographs of each monitoring site are included in Appendix 4.

Table 5. Description of Yolo Bypass Monitoring Sites

Site description	Site ID	Site Type
Sacramento River Overflow at Fremont	1	Input – Sac R overflow
Knight’s Landing Ridge Cut	2	Input - channel
Cache Creek	3	Input - creek
Willow Slough Bypass	4	Input - channel
Yolo Bypass Wildlife Area – lift pump	5	East side drain channel <sup>[1]</sup>
Putah Creek	6	Input - creek
Z Drain – Dixon RCD	7	Input - channel
Sacramento Weir	8	Input – Sac R overflow
Tule Canal – Woodland R1	9	East side drain channel
Tule Canal – Woodland R2	10	East side drain channel
Tule Canal at north-east corner of I-80	11	East side drain channel
Toe Drain at north-east corner of Little	12	East side drain channel

[1] This site contains recirculated water pumped from the Toe Drain.



a)

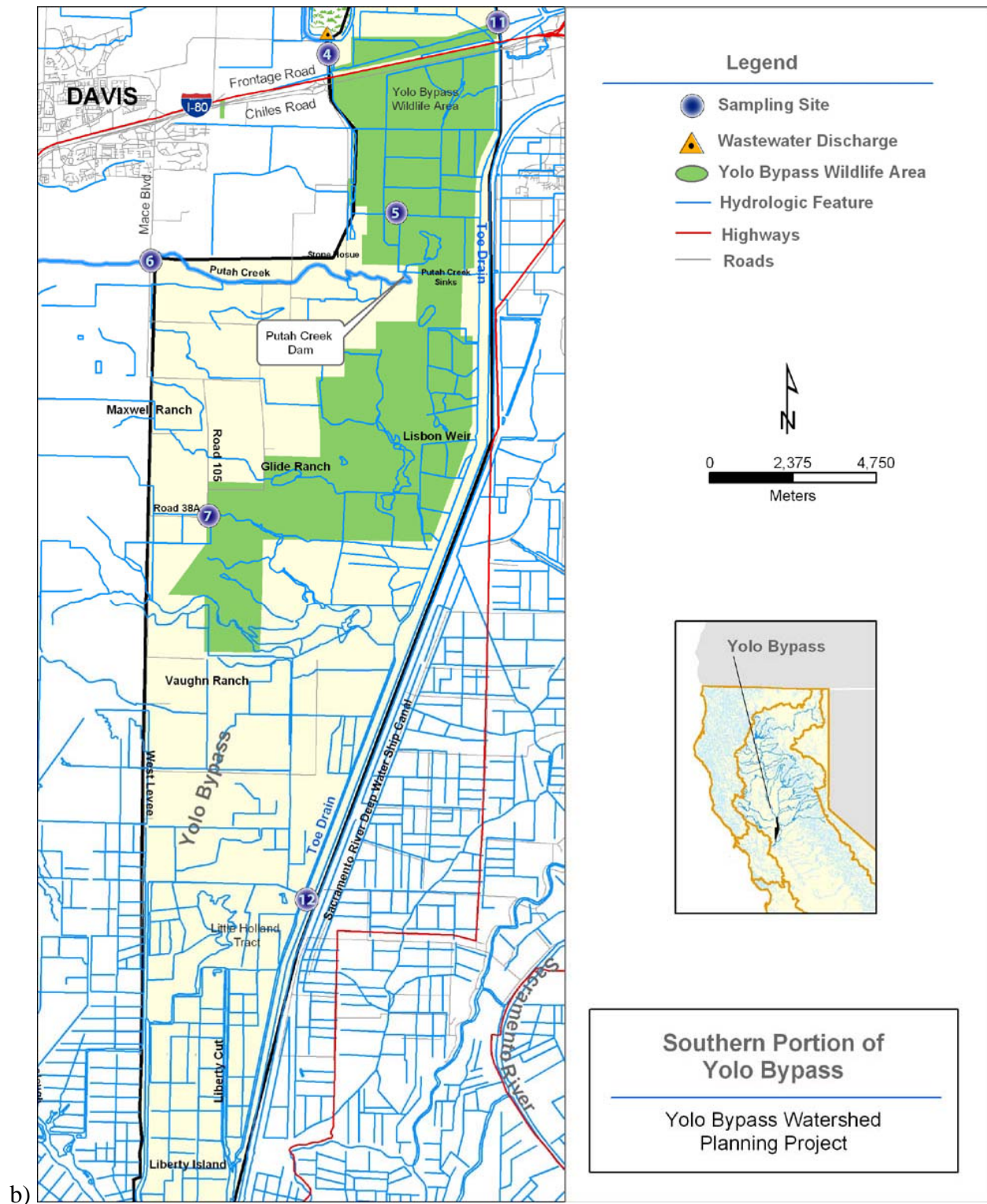


Figure 5. Map of Yolo Bypass water quality monitoring stations for a) northern and b) southern portion.

# Sampling and Analysis Methods

Sampling and analysis methods are described here.

## Quality Assurance Program Plan

The types of quality control assessments used in the Yolo Bypass Monitoring Program are discussed below. Detailed procedures for preparation and analysis of quality control samples are provided in the program's Quality Assurance Project Plan (Appendix 5).

## Site Observations

Site observations were made by field crews before, during, and after each sampling event and noted on the field log. Observations included anything that may potentially impact sample results or that may aid in interpretation of data and/or the collection of samples in future sampling events.

## Field Measurements

Field measurements were collected at each site for each event, and included the following measurements: turbidity, pH, temperature, and electrical conductivity, dissolved oxygen.

## Water Column Samples

Grab samples were collected monthly from each site. Grab samples were collected directly into individual containers for shipment. "Clean sampling" techniques were used for the collection of all water samples in a way that does not contaminate, lose, or change the chemical form of the analytes of interest. Samples intended for mercury analysis were collected using rigorous protocols, based on USEPA Method 1669.

The monitoring program conducted chronic (seven-day), three-species toxicity tests quarterly at four sites: Ridge Cut, Cache Creek, Willow Slough, and Tule Canal. These samples were taken concurrently with water quality samples at the same sites and analyzed for metals, mercury, methylmercury, and pesticides. In addition, the program assisted the Yolo County Farm Bureau with collecting samples for acute (96-hour) toxicity tests in support of a separate monitoring program. Acute toxicity samples were collected at the Z Drain, Tule Canal, and Toe Drain sites for five events (June through October).

## Streambed Sediment Samples

Fine sediments were sampled from streambeds at ten sites in September 2004. Samples from six of these sites (Ridge Cut, Cache Creek, Willow Slough, Putah Creek, Tule Canal, and Toe Drain) were tested for pesticides, metals, mercury, methylmercury, and chronic toxicity, while the other four (Woodland R1, Woodland R2, YBWA, and the Z Drain) were tested only for mercury and methylmercury. Sampling teams collected approximately the top 2 cm of fine surface sediment from the stream bottoms where sediment accumulated. Monthly water quality samples for September were collected concurrent with the sediment collection.

## Sampling Schedule and Review of Monitoring Events

The constituents monitored are shown in Table 6. The sampling schedule is shown in Table 7. Laboratory services were provided by Aqua Science of Davis, CA, CalTest Analytical Laboratory of Napa, CA, Frontier GeoSciences of Seattle, WA, Pacific Ecorisk of Martinez, CA, and BioVir Laboratories of Benicia, CA.

Water column samples were collected on the third week of every month for 12 consecutive months. For all events, 10 sites were visited for collection of field measurements, bacteria and mercury samples. For six of the events, distributed in time, a 'full suite' of samples was collected at several sites: Ridge Cut, Cache Creek, Willow Slough, Putah Creek, Tule Canal, and Toe Drain. The full-suite set of analytes included metals, nitrate, hardness, color, TDS/TSS, TOC/DOC, mercury, methylmercury, bacteria, and pesticides. Four of these six events included the additional collection of chronic, 3-species toxicity samples. During flood conditions (only February 2004) mercury and bacteria samples were collected at the Fremont Weir and Sacramento Weir sites. Flood conditions during this event did not permit access to the Toe Drain or YBWA sites.

Table 6. Summary of constituents and parameters monitored by the project. Sample sites and number of events are shown.

Analyte	Sites	Events
<b>Water Column</b>		
Organophosphate Pesticides by EPA 614/8141	6	6
Chlorinated Pesticides by EPA 608/8081	6	6
Carbamates by EPA 632/8032	6	6
Ultra Trace Mercury (total)	10	12
Methyl Mercury	6	6
Metals (Al, B,Cu, Be, CrIII, Pb, Se)	6	6
Nitrate	6	6
Hardness	6	6
Color	6	6
TDS	6	6
TOC	6	6
DOC	6	6
TSS	6	6
Total & Fecal Coliform, and <i>E. coli</i>	10	12
3-Species Chronic Toxicity	4	4
<b>Field Measurements</b>		
Electrical Conductivity	10	12
Turbidity	10	12
Dissolved Oxygen	10	12
pH	10	12
Temperature (F)	10	12
<b>Sediment</b>		
Organophosphate Pesticides by EPA 614/8141	6	1
Chlorinated Pesticides by EPA 608/8081	6	1
Carbamates by EPA 632/8032	6	1
Ultra Trace Mercury (total)	10	1
Methyl Mercury	10	1
Metals (Al, B,Cu, Be, CrIII, Pb, Se)	6	1
TOC	10	1
2-Species Chronic Toxicity	6	1

Table 7. Sampling schedule for analytes by site and event.

SITE		EVENTS											
		Nov 1	Dec 2	Jan 3	Feb 4	March 5	April 6	May 7	June 8	July 9	Aug 10	Sept 11	Oct 12
Class	No.												
Inputs	1				1, 2, 4								
	2	1, 2, 3, 4	1	1, 2, 3, 4, 5	1	1	1, 2, 3, 4, 5	1	1, 2, 3, 4	1,	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1
	3	1, 2, 3, 4	1	1, 2, 3, 4, 5	1	1	1, 2, 3, 4, 5	1	1, 2, 3, 4	1	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1
	4	1, 2, 3, 4	1	1, 2, 3, 4, 5	1	1	1, 2, 3, 4, 5	1	1, 2, 3, 4	1	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1
	5	1	1	1			1	1	1	1	1	1	1
	6	1, 2, 3, 4	1	1, 2, 3, 4	1	1	1, 2, 3, 4	1	1, 2, 3, 4	1	1, 2, 3, 4	1, 2, 3, 4	1
	7	1, 3	1	1, 3	1	1	1, 3	1	1, 6	1, 6	1, 3, 6	1, 3, 6	1, 6
	8				1, 2, 4								
East Channel	9	1, 3	1	1, 3	1	1	1, 3	1	1	1	1, 3	1, 3	1
	10	1	1	1	1	1	1	1	1	1	1	1	1
	11	1, 2, 3, 4	1	1, 2, 3, 4, 5	1	1	1, 2, 3, 4, 5	1	1, 2, 3, 4, 6	1, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 6
	12	1, 2, 3, 4		1, 2, 3, 4		1	1, 2, 3, 4	1	1, 2, 3, 4, 6	1, 6	1, 2, 3, 4, 6	1, 2, 3, 4, 6	1, 6

1 = Total Mercury and Total and fecal coliforms, including E. Coli (10/12)

2 = Methylmercury and Trace Metals (6/6)

3 = Pesticide group: Chlorinated, organophosphates and carbamates (6/6)

4 = General constituents: Hardness, TOC, DOC, TSS, TDS, Color, and Nitrate (6/6)

5 = Chronic 3-Species Toxicity (4/4)

6 = Acute 3-Species Toxicity, TSS/TDS, Color, TOC/DOC, UV Absorption (3/5)

Grey indicates site sampled only when weir is breached

## Summary of Monitoring Results

The analytical results for water column and streambed sediment samples are presented in Appendix 6-A. Descriptive statistics of the water column monitoring data are presented in Appendix 6-B. For pesticides, only detected chemicals are tabulated. Because of the small number of samples, there was no attempt to develop statistical distributions of the data. To calculate mean values, non-detected values are assumed to be half of their detection limit. Also, exceedances of water quality objectives are quantified as the number of detected samples exceeding the applicable criterion. An assessment of water quality based on these results is presented in the next section.

### Water Column Samples

Six samples from six sites were analyzed for total and dissolved metals, total and dissolved solids, nitrate, boron, hardness, methylmercury, organic carbon, and pesticides (OCs, OPs, and carbamates). Total mercury, bacteria, and conventional parameters (EC, temperature, DO, color) were analyzed almost monthly at all 12 sites. Access to the Yolo Basin Wildlife Area and the Toe Drain sites was not possible on two occasions.

Water column samples from four representative sites were analyzed on four events for chronic toxicity. Water column samples from three representative sites were analyzed on five events for acute toxicity. One sample from each of three sites – Ridge Cut, Z Drain, and Toe Drain exhibited toxicity to fathead minnows only. No other samples exhibited acute or chronic toxicity to the test organisms.

### Streambed Sediment Samples

Streambed sediment samples were collected for the September 2004 sampling event at six sites and analyzed for metals, organic carbon, and a full suite of OP, OC, and carbamate pesticides. Aluminum content in sampled sediments was lower than in water column samples. Mercury content was high in Putah Creek (0.6 mg/kg) but low elsewhere. The next highest mercury content was Cache Creek, with a content of 0.22 mg/kg, approximately the content in native soil. Other metals analyzed were either nondetected or not of concern. All samples were below analytical detection limits for pesticides except for one sample from Putah Creek having detectable 4,4'-DDE.

Streambed sediment samples were tested for chronic toxicity on one event. Significant survival and growth effects on both test organisms (the amphipod *Hyalella azteca* and the midge *Chironomus tentans*) were found for the Knights Landing Ridge Cut site. In addition, survival and growth of the midge was significantly lower in samples from Tule Canal, Putah Creek, and Toe Drain.

### Flow Rate Estimates

Flow rates at each sampling site were estimated for each event by various methods. The estimated flow rates are shown in Table 8. Accurate estimates during low-flow conditions were often not feasible at several sites. One inconsistency observed is that estimated flow rates decrease downstream from Fremont Weir to Tule Canal during the wet season. The Bypass is considered “flooded” when flow rate exceeds approximately 3500 cfs. This level was exceeded during the monitoring period only in February.

Table 8. Estimated flow rates (in cubic feet per second) at sampling sites during sampling.

Site Name:	Fremont Weir	Ridge Cut	Cache (CCY, Yolo)	Willow Slough Bypass	YBWA	Putah Cr.	Z Drain	Sacra-mento Weir	Tule Canal (R1) <sup>[4]</sup>	Tule Canal (R2)	Tule Canal (R3)	Toe Drain (Lisbon)
Site #:	1	2	3	4	5	6	7	8	9	10	11	12
Area (acres):	13,000,000	1,000,000	740,000	103,000	n/a	440,000	20,000	n/a	n/a	n/a	n/a	n/a
Date												
11/23/03	*	12	4	< b	[1]	21	1	[2]	140	140	[3]	< a
12/20/03	*	nr	97	3		70	1		904	904		< a
01/23/04	*	15	62	18		126	2		895	895		1,749
02/21/04	73,570	nr	3,620	nr		235	<1		45,800	45,800		3,367
03/27/04	*	nr	332	10		235	2		950	950		1,938
04/23/04	*	< b	49	1		85	<1		355	355		686
05/22/04	*	< b	8	60		58	20		< a	< a		189
06/26/04	*	< b	10	28		43	22		< a	< a		24
07/24/04	*	< b	15	15		35	10		< b	< b		61
08/20/04	*	< b	< b	17		35	11		< b	< b		155
09/21/04	*	< b	5	< b		8	35		< a	< a		146
09/22/04	*	< b	5	< b		11	35		< a	< a		118
10/23/04	*	nr	40	< b		13	6		< a	< a		67

\* No water

nr = not recorded

< below detection limit of field meter or gage:

a. USGS or DWR Gage Limit is 100 cfs.

b. Marshall-McBirney Flowmate 200 Field Flow Meter, reading less than 1 ft/s.

[1] Water is pumped into the wetlands from a canal connected to the Toe Drain. Withdrawn water is pumped to farmland west of the Bypass or recycled.

[2] Water did flow over the Sacramento Weir in February 2004, but flow rates are not reported.

[3] Flows at this site were not measured because of logistic constraints.

[4] Flows at R-1 are essentially equivalent to measured flow at R-2 minus City of Woodland effluent discharges, which average less than 15 cfs.

# ASSESSMENT OF CURRENT WATER QUALITY

Current water quality is assessed for the specific POCs in each pollutant category that indicate some potential for exceedances of water quality criteria. The assessments are based primarily on the data collected during this study but also consider historical data. This section concludes with a prioritization of the POCs based on this analysis.

The format for assessing each type of POC is as follows.

- Describe the POCs and the basic issues that they present – reiterating some of the reasoning for selecting the POCs while providing additional context for the assessment.
- Assess any spatial patterns discernible in the dataset for 12 monitoring stations – compare concentrations for groups of sites:
  - **“AgDrain”**: Agricultural drains of Knights Landing Ridge Cut, Willow Slough Bypass, and Z Drain;
  - **“Flood”**: Sporadic flood discharges over Fremont Weir and Sacramento Weir;
  - **“InBypass”**: In-Bypass flows in Tule Canal (sites R-1, R-2, and I-80), Yolo Basin Wildlife Area, and the Toe Drain; and
  - **“WestTrib”**: Regularly-flowing west-side tributaries of Cache Creek and Putah Creek.
- Assess any temporal patterns discernible in the dataset for 12 monitoring events – compare concentrations and loads for events and seasons:
  - Flood events (February data for the two weir sites);
  - Wet season (December – April); and
  - Dry season (May – November).
- Describe in general terms the conceptual model, identifying likely sources and sinks to which the patterns can be attributed.

A POC could be associated with suspended material because of several reasons, including: it is a natural component of soil, it is applied to or deposited on soil and enters water concurrent with soil erosion, and it adsorbs to soil or suspended organic material. Correlations between various POCs and TSS or discharge are generally not feasible because TSS was measured on only six occasions and discharge was immeasurably low at many sites much of the year. But POCs are compared to TSS and discharge at selected sites to identify any potential correlations.

Spatial and temporal patterns in the Bypass are summarized in Table 9 based on average concentrations. Consistent with the data summaries presented in the previous section, one-half of the detection limit was substituted for non-detected values. For pesticides, which were rarely detected, the values presented are the averages of detected samples only.

Table 9. Average water column concentrations for POCs grouped by site characterization and season.

Characterization <sup>[1]</sup> =			AgDrain			Flood	InBypass			WestTrib		
Season <sup>[2]</sup> =			All	Wet	Dry	n/a	All	Wet	Dry	All	Wet	Dry
POC	Units	Criteria <sup>[3]</sup>										
<i>Averages of all values</i>												
E. Coli	MPN/100mL	126	4,215	4,643	3,754	4,000	1,355	2,266	562	599	535	928
Fecal Coliform	MPN/100mL	200	4,991	4,192	5,121	6,000	1,995	2,936	1,299	651	539	1,012
Total Coliform	MPN/100mL	--	43,961	25,045	61,605	8,000	25,653	24,146	25,738	10,222	5,223	14,474
Boron	ug/L	700	1,347	1,053	1,494	NA	934	650	1,076	1,062	973	1,106
Boron, dissolved	ug/L	--	1,320	970	1,495	NA	818	610	921	926	940	919
Aluminum	ug/L	87	1,958	1,575	2,150	NA	2,575	2,400	2,663	883	545	1,053
Aluminum, dissolved	ug/L	--	7.1	11.3	5.0	NA	11.7	17.5	9	7.1	7.5	7
Chromium(III)	ug/L	340	7.3	5.2	8.4	NA	9.0	8.2	9	5.4	5.1	6
Chromium(III), dissolved	ug/L	395	1.47	1.48	1.46	NA	1.17	1.60	1	2.53	3.73	2
Copper	ug/L	18.3	6.6	6.0	6.9	NA	7.6	7.3	8	3.5	2.8	4
Copper, dissolved	ug/L	17.6	2.62	2.75	2.55	NA	2.77	2.63	3	1.66	1.53	2
Lead	ug/L	8.68	1.15	0.95	1.25	NA	1.17	1.18	1	0.53	0.35	1
Lead, dissolved	ug/L	5.9	0.15	0.19	0.13	NA	0.15	0.19	0.1	0.14	0.19	0.1
Methylmercury	ng/L	0.06	0.34	0.28	0.38	NA	0.33	0.49	0.26	0.33	0.38	0.30
Total Mercury	ng/L	51	9.4	6.7	11.7	22	13.7	12.6	14	10.5	10.3	10
Selenium	ug/L	5	2.8	2.6	2.9	NA	0.91	1.13	1	1.13	0.73	1
Selenium, dissolved	ug/L	--	2.5	2.3	2.6	NA	0.98	1.00	1	0.85	0.93	1
Nitrate	mg-N/L	10	0.73	0.41	0.89	NA	1.72	0.60	2	3.10	2.98	3
Total Organic Carbon	mg/L	--	8.6	10.5	8.0	NA	7.5	7.5	8	4.8	4.8	5
Dissolved Organic Carbon	mg/L	--	8.2	7.8	8.3	NA	7.1	7.5	7	4.7	4.8	5
EC	umhos/cm	700	797	786	787	120	607	548	661	532	514	542
TDS	mg/L	450	494	485	498	NA	381	335	400	328	328	329
TSS	mg/L	--	69	55	74	NA	58	62	56	21	22	21
<i>Averages of detected values</i>												
Diuron	ug/L	10	0.32	0.55	0.17	NA	0.30	0.40	0.10	ND	ND	ND
Methomyl	ug/L	0.52	ND	ND	ND	NA	ND	ND	ND	0.7	0.7	ND
4,4'-DDE	ug/L	0.00059	0.01	ND	0.01	NA	ND	ND	ND	ND	ND	ND
Chlorpyrifos	ug/L	0.009	0.03	0.04	0.01	NA	ND	ND	ND	0.02	0.02	0.02
Diazinon	ug/L	0.1	0.03	0.03	ND	NA	ND	ND	ND	0.04	ND	0.04

[1] Sites aggregated into these site categories are indicated in the text.

[2] "Wet" season includes December-April; "dry" season is all other months.

[3] Indicating lowest potentially applicable criteria, as presented in the report.

"NA" indicates that no data are available; no samples were collected.

"ND" indicates that all samples were nondetected.

## Bacteria

Bacteria indicators were monitored to represent the potential presence of pathogens. Bacteria were measured as total coliform, fecal coliform and *E. coli* concentrations in water column samples. These bacteria may come from human as well as domestic animals and wildlife feces; therefore, sources can not be positively identified. These bacteria indicators are also naturally present in soil and may degrade or proliferate depending on their aquatic environment. The local concern is with humans recreating in the Bypass waters and the use of such waters to irrigate agricultural food crops. Contact with human skin can cause rashes, while ingestion can cause illness. The concern in the Delta is for the protection of drinking water sources.

Bacteria were among the POCs monitored monthly at all 12 sites. The criteria are based on the geometric mean of multiple samples taken during a 30-day period, but are compared to the individual sample results and to average values for sampling sites. Almost all fecal coliform were determined by analyses to be *E. coli*.

### Spatial Patterns

The two agricultural drains Willow Slough Bypass and Z Drain had among the three highest median concentrations of all three bacteria indicators. The two west-side Cache and Putah Creeks ranked among the lowest concentrations of all three bacteria indicators. Flows over the Fremont and Sacramento Weirs, sampled only once, were within the range of concentrations measured elsewhere on the same occasion. In-Bypass sites had concentrations ranking in the middle to lower third of the sites and do not portray any consistent downstream pattern. All sites exceeded the 200 MPN/100mL objective for fecal coliform on at least one occasion. Concentrations in the agricultural drains Willow Slough Bypass and Z Drain regularly exceeded the proposed 126 MPN/100mL objective for *E. coli*. All other sites except the Yolo Basin Wildlife Area exceeded the proposed objective at least once.

### Temporal Patterns

Bacteria indicators did not portray any clear seasonal patterns. Bacteria indicators are notoriously variable in the environment, and the data collected during this study is consistent with that pattern. Data for several sites indicate fluctuations of two orders of magnitude in fecal coliform and *E. coli* from one month to the next.

### Conceptual Model

Bacteria concentrations were measured highest in runoff from rural areas. Total coliform is very poorly correlated with TSS data for the Willow Slough Bypass (Figure 6), indicating that eroded soil may not be the main contributor. Wildlife using the Bypass throughout the year could have caused bacteria levels in the Bypass to remain steady. Degradation and sequestration in local soil are dominant sinks or losses of bacteria.

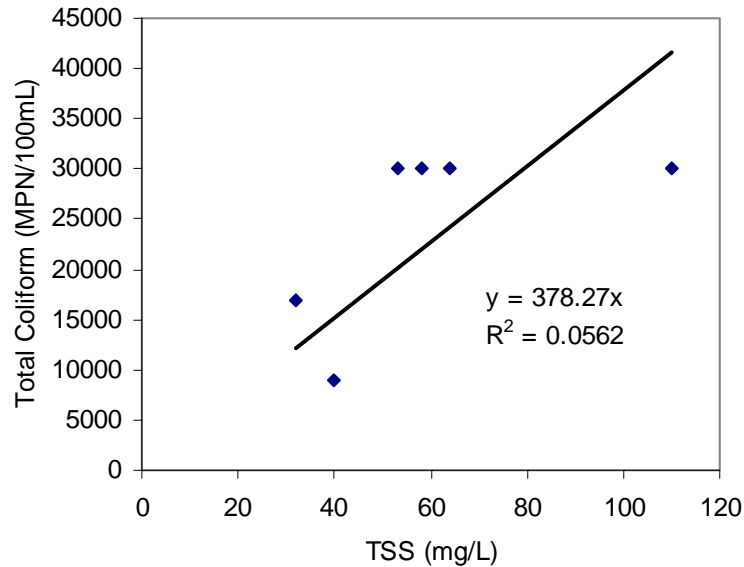


Figure 6. TSS versus total coliform concentrations in Willow Slough Bypass samples. There is no criterion for total coliform.

## Boron

Boron was monitored to identify potential sources and seasonal conditions. Boron has many properties similar to salinity. Boron is a concern because of potential impacts to agricultural production.

### Spatial Patterns

Boron concentrations do not portray any clear spatial patterns. Cache Creek had the highest median concentration among all sample sites while its southern neighbor Putah Creek had the lowest. Only Putah Creek had average boron concentrations below the 700 ug/L criteria. Willow Slough Bypass, between those two tributaries, had the second highest median concentration. Overall, boron concentrations are generally higher than measured previously at the same locations by Schemel et al. (2002). Yet the average boron concentration in Cache Creek is half of the concentration measured regularly by the YCFCWCD (2000).

### Temporal Patterns

For each type of monitoring site, average dry season boron concentrations were higher than wet season concentrations. All summertime flow in Cache Creek is diverted at Capay onto local farms, so any/all water passing through the Cache Creek Settling Basin during summer is irrigation tailwater or runoff from groundwater pumping. However, total boron concentrations do not indicate a seasonal or flow-based pattern at the Cache Creek site (Figure 7).

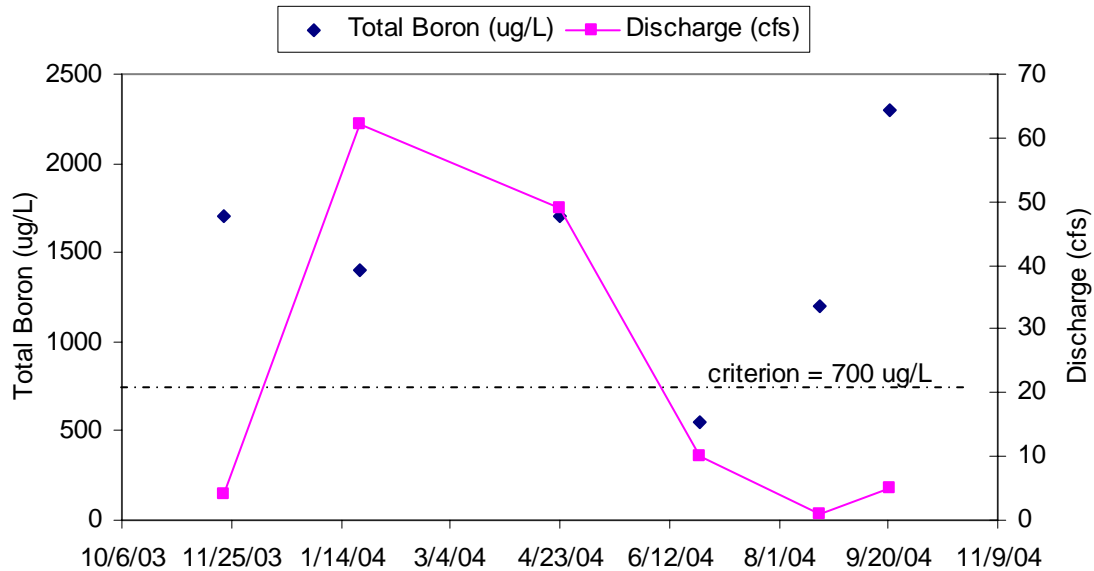


Figure 7. Total boron concentrations and flow rate measured in Cache Creek.

### Conceptual Model

Recognizing that dry season concentrations of boron are generally higher than wet season concentrations, potential sources are groundwater wells and groundwater seepage. This condition points to natural marine sediments sources leached into water that eventually becomes surface runoff. Evapotranspiration likely increases concentrations. A better quantification of source waters is needed to verify sources of boron in the Cache Creek watershed.

## Aluminum

Aluminum is a metal addressed separately because of the high levels detected.

### Spatial Patterns

For the entire project dataset, only one sample (from Putah Creek) was measured *below* the total aluminum criterion of 87 ug/L. Total and dissolved aluminum concentrations were highest at the two most downstream sample sites, Tule Canal at I-80 and the Toe Drain. Total aluminum concentrations at these two sites correlated well with TSS (Figure 8). These data indicate that 4.5% of the TSS is aluminum by weight, which is less than its concentration in benchmark (i.e., undisturbed) soils collected in Yolo County (Bradford et al., 1996) and in tributary sediments (Maccoy and Domagalski, 1999). The dissolved fraction did not correlate with pH levels (not shown). Streambed sediment samples collected in September 2004 did not correlate with median water column concentrations (not shown).

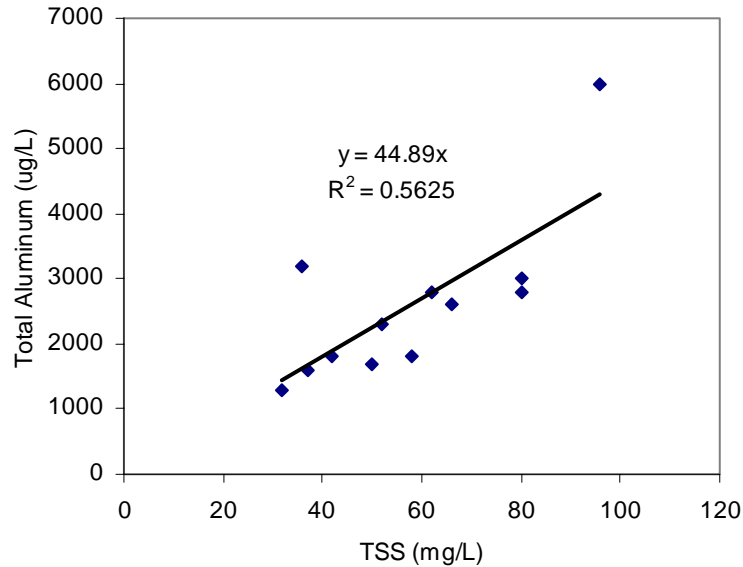


Figure 8. TSS versus total aluminum concentrations for combined Tule Canal at I-80 and Toe Drain sites' data. The criterion of 87 ug/L is indistinguishable at the bottom of the scale of this figure.

### Temporal Patterns

Aluminum did not portray any clear seasonal patterns.

### Conceptual Model

Aluminum content in TSS is within the range of background soil content. Thus, the primary source of aluminum appears to be native, undisturbed soil. Dissolved aluminum is the form generally considered toxic to aquatic organisms. However, there is no predictable relationship found between total and dissolved aluminum concentrations. The ratios of dissolved to total aluminum for in-Bypass samples are not consistent and do not correlate with instantaneous pH readings.

## Mercury

Mercury is a metal addressed separately because of the high levels detected. The regional concern with mercury is accumulation of methylmercury in the food web and transport to the Delta.

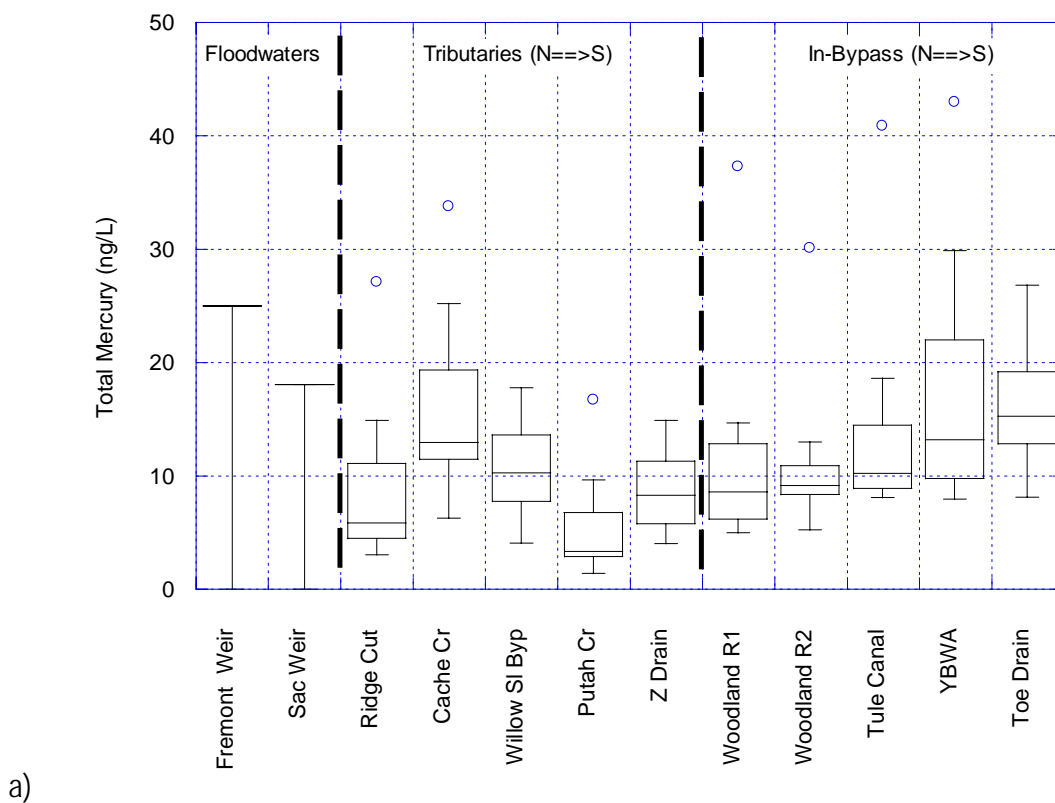
### Spatial Patterns

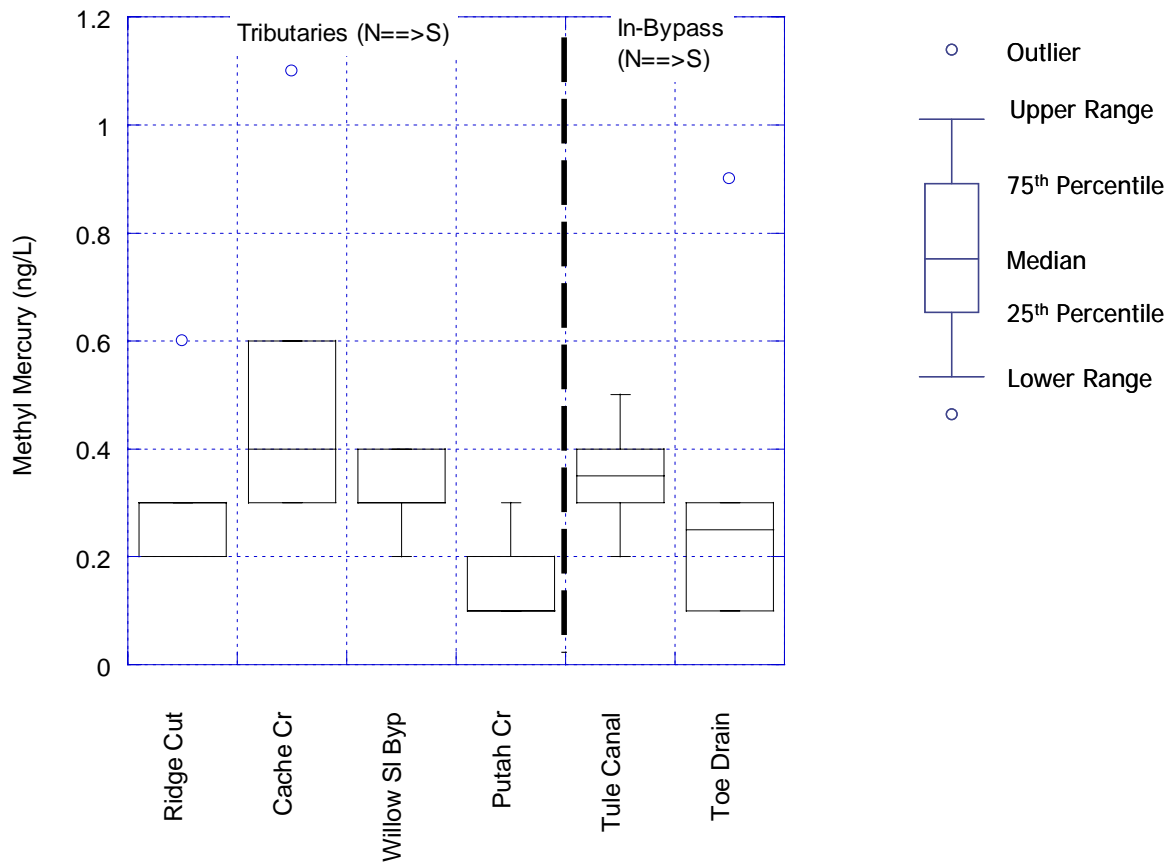
Total mercury and methylmercury concentrations are summarized in Figure 9 as box plots. Total mercury concentrations were higher in flood waters over the Fremont and Sacramento Weirs than in all other sites. Assuming that the single sample of Fremont Weir water is representative of that source, 140 pounds of mercury were discharged into the Bypass during the sampling period. For perspective, this load is approximately 100 times the average annual load from all municipal wastewater treatment plants into the Bypass combined but one-tenth of the total load to San Francisco Bay. The next two highest were the southern-most points in the Bypass, Tule Canal at I-80 and the Toe Drain. Cache Creek had the highest methylmercury concentration while Putah Creek had the lowest.

No samples exceeded the applicable total mercury criterion of 51 ng/L, while all samples exceeded the potentially applicable methylmercury criterion of 0.06 ng/L. Within the Bypass, total mercury concentrations consistently increased from upstream to downstream sites. Methylmercury concentrations were monitored within the Bypass only at Tule Canal at I-80 and the Toe Drain. The median methylmercury concentration at the downstream site was lower than at the upstream site, contrary to the expectation that Bypass wetlands would increase methylmercury concentrations. Methylmercury concentrations measured at the in-Bypass sites are consistent with other reported data.

The load of total mercury from Cache Creek to the Bypass was approximately 26 pounds for the 12-month monitoring period, less than 20% of the load from the Fremont Weir which occurred over a roughly one-month period.

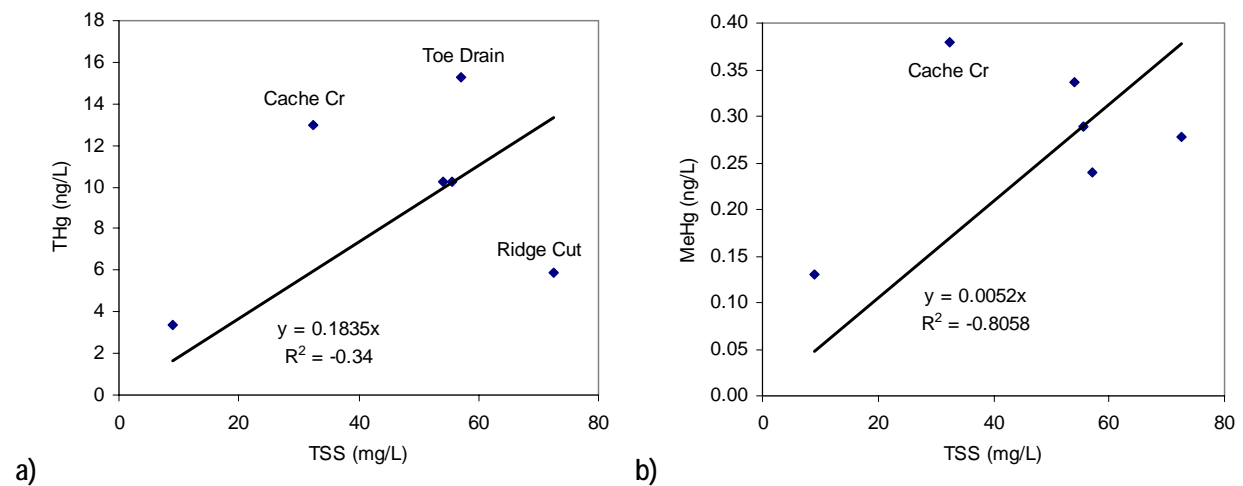
Total mercury and methylmercury concentrations are plotted against TSS in Figure 10.





b)

Figure 9. Box plots of a) total mercury and b) methylmercury concentrations at all sample sites.



a)

b)

Figure 10. Average TSS versus average a) total mercury (THg) and b) methylmercury (MeHg) concentrations for all sites monitored for mercury. The linear regressions are not valid, but are used to indicate relative ratios.

A similar comparison among sites can be made for mercury content in sediments (Figure 11). Results for Putah Creek indicate by far the highest content of total mercury but average content of methylmercury. The Yolo Bypass Wildlife Area (YBWA) sample had exceptionally high methylmercury content but average total mercury content. The correlation did not improve by normalizing to TOC, as suggested elsewhere (Krabbenhoft et al., 1999).

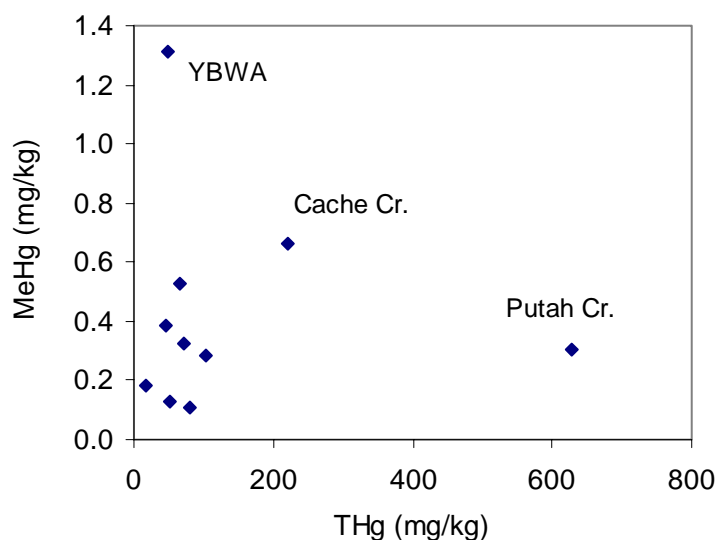


Figure 11. Total mercury (THg) versus methylmercury (MeHg) content in sediments collected at each sample site.

### Temporal Patterns

Methylmercury concentrations were higher on average in the wet season than in the dry season in the Bypass and in west-side tributaries. This finding is consistent with the full data record. Total mercury and methylmercury concentrations in Cache Creek are shown in Figure 12. There is no discernible seasonal pattern or correlation with discharges at this site regularly referred to as a major source of mercury in the Bypass.

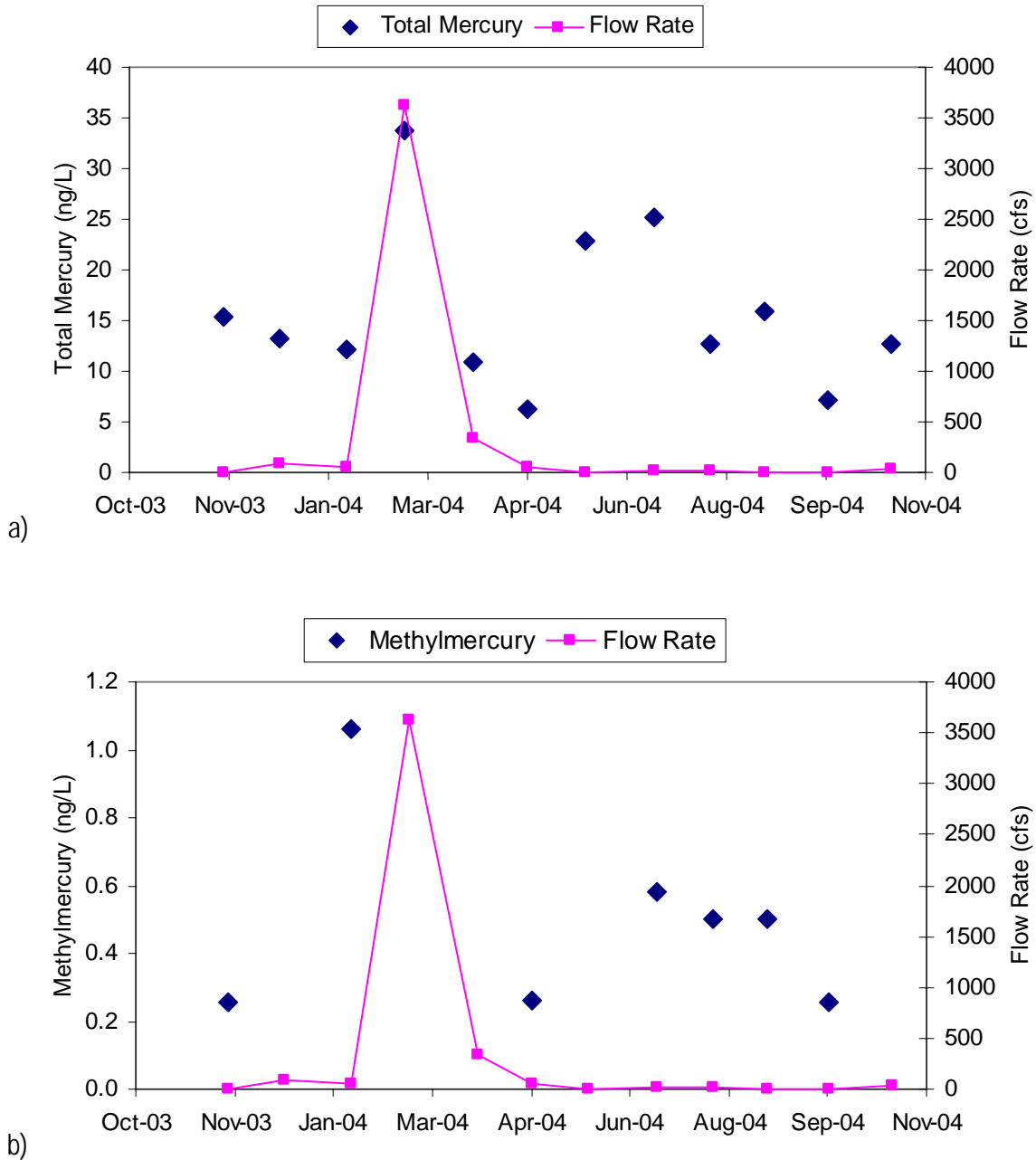


Figure 12. Concentrations of a) total mercury and b) methylmercury in Cache Creek plotted along with flow rate. The total mercury criterion of 50 ug/L is above the scale on Figure a; the methylmercury criterion of 0.06 ug/L is indistinguishable at the bottom of the scale in Figure b.

### Conceptual Model

Mercury sources to water can include the following:

- Atmospheric deposition
- Permitted discharges of treated wastewater

- Erosion of native sediment
- Urban runoff
- Discharges from naturally occurring mineral springs
- Erosion and leaching from inactive mercury mining sites
- Erosion and leaching from historic gold mining sites.
- Re-suspension of contaminated sediments.
- Erosion and leaching of pesticide residue in soils
- Releases from other mineral mines and waste disposal sites

Mercury mines in the Cache and Putah Creek watersheds supplied mercury amalgam for gold mining in the Sierras and other industrial uses. While a portion of the mine waste is still on these abandoned sites, larger volumes of waste now reside downstream in streambank and streambed repositories. High releases from Clear Lake and Indian Valley Reservoir appear to erode large volumes from these repositories along the mainstem of Cache Creek (CVRWQCB, 2004).

Slotton and Ayers (2004) found that the Cache Creek Nature Preserve, discharges from which seep into lower Cache Creek, functions as a source of methylmercury. Mercury levels in fish collected from within the Preserve are elevated; however, monitoring did not indicate any downstream effects. This finding is consistent with the findings from this project's data that methylmercury concentrations did not increase progressing downstream through the Bypass.

Sinks or losses of total mercury and methylmercury include volatilization, sequestration in local soil and biouptake. Losses of total mercury within the Bypass are likely insignificant. Demethylation of methylmercury is likely the major loss mechanism for this form.

Total mercury versus TSS in Cache Creek is plotted in Figure 13. The slope of the linear regression indicates a content of 0.4 ppm, compared to the average content of regional background soil in non-mineralized areas 0.2 mg/kg (Churchill and Clinkenbeard, 2002). This content estimate is consistent with the historical data reported by others and used in the Cache Creek mercury TMDL (CVRWQCB, 2004).

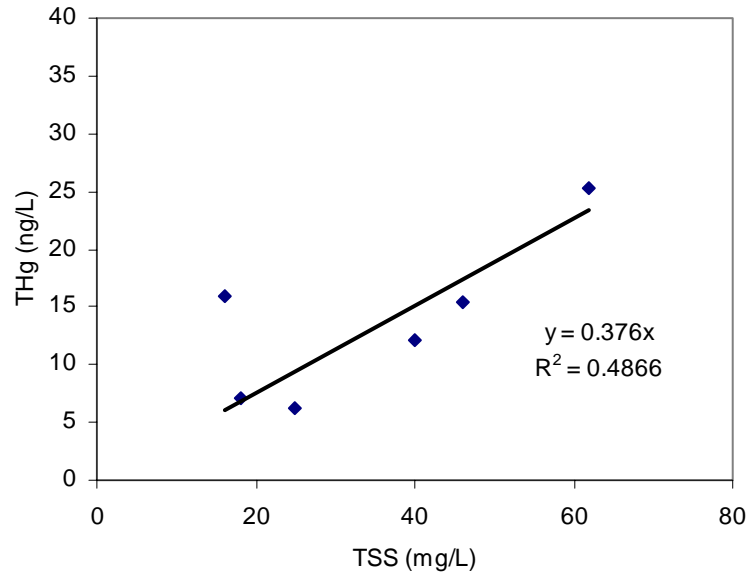


Figure 13. TSS versus total mercury concentrations in Cache Creek. The criterion of 51 ug/L is above the scale of this figure.

Mercury concentrations measured at the two in-Bypass monitoring sites are plotted against concurrent TSS concentrations in Figure 14. The slope of the linear regression in Figure 14a indicates a content of 0.23 ppm, essentially the average content of regional background soil in non-mineralized areas.

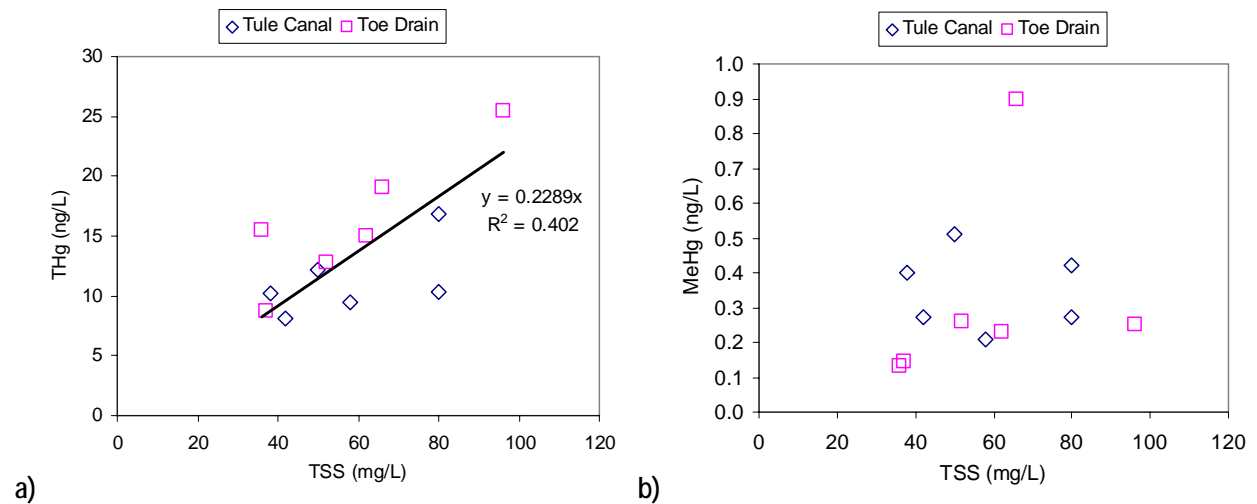


Figure 14. TSS versus a) total mercury and b) methylmercury concentrations in Tule Canal and Toe Drain sample results. Methylmercury is not correlated with TSS.

## Other Metals

Other metals are assessed expeditiously because of the low concern for these POCs: chromium, copper, lead, and selenium.

### Spatial Patterns

Total and dissolved chromium(III) concentrations were generally an order of magnitude or more below the chromium(III) criterion at all sites.

No samples approached the dissolved copper or lead criteria. The west-side tributaries consistently had the lowest copper and lead concentrations. The two sites lowest in the Bypass, Tule Canal at I-80 and the Toe Drain, tended to have among the highest total and dissolved copper concentrations.

Although three sites had samples measured at or above the selenium criterion (5 ug/L), no sites had average total selenium concentrations at that level. The two agricultural drains Knights Landing Ridge Cut and Willow Slough Bypass has the highest total and dissolved selenium concentrations.

### Temporal Patterns

None of the other metals portrayed any clear seasonal patterns.

### Conceptual Model

Sinks or losses of other metals include transport in surface water to the Delta, sequestration in local soil and biouptake. Losses of these metals within the Bypass are likely insignificant.

## Nitrate

Nitrate is a concern to humans because it causes a potentially lethal blood disorder called Methemoglobinemia, known as “blue baby syndrome”. Nitrate is a concern in surface waters because it can enhance the growth of algae and plants beyond natural or desired levels, in a process called eutrophication. Eutrophication can be detrimental locally if it causes exaggerated daily reductions in dissolved oxygen, leading to fish kills. Eutrophication is detrimental to water supplies primarily by increasing concentrations of filterable algae and causing pH to fluctuate.

### Spatial Patterns

Cache and Putah Creeks had the highest nitrate concentrations, although median concentrations were below 1.5 mg-N/L at all sites. These values are substantially lower than the criteria of 10 mg-N/L.

### Temporal Patterns

Average nitrate concentrations were lower in the dry season compared to the wet season for each site type.

### Conceptual Model

Nitrate concentrations found during this study contrast with data collected previously by Schemel et al. (2002), which showed lower nitrate concentrations during inundation of the Bypass and average

concentrations of approximately 50 mg/L and as high as 360 mg/L. These data appear erroneous. Other data reported by USGS (Domagalski et al., 2000) suggest that nitrite+nitrate concentrations in the Colusa Basin Drain range from 0.2 to 1.0 mg/L with a median of 0.4 mg/L. These concentrations are essentially equivalent to concentrations measured during this project.

Sinks or losses of nitrate include sequestration in local soils and plant material, and denitrification leading to volatilization of nitrogen gas. The dominant loss mechanism is likely denitrification.

## Organic Carbon

Organic carbon was monitored at the level of total and dissolved concentrations. The concern with organic carbon is that more of it produces more trihalomethanes, a carcinogenic by-product of chlorination for drinking water supplies. There is no criterion except an appreciation that less is better for drinking water supplies.

### Spatial Patterns

Total and dissolved organic carbon tended to be higher in the two agricultural drains, Knights Landing Ridge Cut and Willow Slough Bypass, and in the Toe Drain, while Putah and Cache Creeks had lower concentrations. The percentage of streambed sediment that was TOC was highest in Cache Creek but among the lowest in Putah Creek. This difference between agricultural runoff and major creeks is consistent with the findings by Schemel et al. (2002).

The total organic carbon was almost entirely dissolved. This contrasts the findings by Schemel et al. (2002) that approximately half of the organic carbon was in particulate form.

### Temporal Patterns

There was no clear difference in wet versus dry season concentrations of total or dissolved organic carbon. These data do not corroborate the findings by Schemel et al. (2002) that DOC in the Yolo Bypass was lowest during the inundation period, and then increased in late March to values that were relatively stable for the remainder of the study.

### Conceptual Model

Organic carbon appears to come from multiple sources, contributing throughout the year. The majority of the carbon is dissolved, indicating that structural control measures that settle out particulate material would be ineffective at reducing organic carbon loads. Sinks or losses of organic carbon include sequestration in local soils. Losses of total organic carbon within the Bypass are likely insignificant.

The TOC data in sediment samples do not support any correlations with mercury content or methylmercury production.

## Pesticides

While entire classes of pesticides were monitored, only five were ever detected. Only the detected pesticides are assessed here:

- Organochlorine – DDT is classified as an organochlorine (OC) pesticide. DDT breaks down to DDE in the environment. This class of compounds is generally characterized as having a high tendency

to partition to particles, bioaccumulative, and persistent in the environment. DDT was once widely used to control insects on agricultural crops and insects that carry diseases like malaria and typhus. Its use in the US has been banned since 1972. It may be present in soils and water from air transported globally or evaporated locally. The primary concerns with DDT in the environment are chronic toxicity to aquatic organisms and carcinogenic effects to consumers of contaminated fish. 4,4'-DDE was detected in three samples, all of which exceeded the applicable criterion. The only detected pesticide in sediment samples was 4,4'-DDE, but in Putah Creek (*not* one of the three sites where DDE was detected in the water column. DDT was not detected in any samples.

- Organophosphate – Diazinon and chlorpyrifos are organophosphate (OP) pesticides. In recent years they have been widely used insecticides in agricultural and urban areas. These pesticides are used on orchard crops during the dormant season (i.e., the wet season). Diazinon and chlorpyrifos are being phased out by a federal ban for most residential and commercial uses, although agricultural uses continue. Diazinon was never measured as exceeding its applicable criterion, while the four samples with detectable concentrations of chlorpyrifos all exceeded its applicable criterion.
- Carbamates – Diuron is a carbamate pesticide that works by inhibiting photosynthesis. It is used locally to control a wide variety of annual and perennial broadleaf and grassy weeds. It is used on non-crop areas and many agricultural crops such as fruit, alfalfa, and wheat. Diuron is moderately to highly persistent in soils and surface water. Methomyl is a carbamate pesticide used for summertime worm control on alfalfa. Although detected, concentrations of diuron and methomyl never exceeded their applicable criteria. Carbamate pesticides used in rice cultivation include predominately thiobencarb and molinate, but neither of these chemicals was monitored.

Pyrethroids are another class of pesticides that are becoming more popular as uses for the organophosphates are phased out. Pyrethroids are synthetic chemical insecticides that act in a similar manner to pyrethrins, a natural chemical derived from chrysanthemum flowers. Pyrethroids are widely used for controlling various insects, including mosquitoes. Pyrethrin is extremely toxic to fish while slightly toxic to bird species, such as mallards. They degrade rapidly and thus do not tend to persist in the environment or bioaccumulate. Pyrethroids were not monitored for this project, but are discussed within the realm of potential pesticides in the Bypass.

## Spatial Patterns

Four of the five detected pesticides were detected in the Knights Landing Ridge Cut. Three of the four detected pesticides were detected in the Willow Slough Bypass, also representing agricultural runoff. 4,4'-DDE, the primary degradation product of DDT, was detected at both of these sites. Methomyl and diazinon were also detected in Cache Creek.

National Water Quality Assessment Program (NAWQA) data suggest that Colusa Basin Drain water was among the nation's most degraded sites in terms of OP insecticide concentrations (Domagalski et al., 2000). But this study's data indicate that Knights Landing Ridge Cut, which conveys Colusa Basin Drain water, rarely exceeded the chlorpyrifos criterion and never exceeded the diazinon criterion. This finding is most likely the combined result of two factors: (1) OP pesticide use in the watershed has decreased, and (2) pesticide management practices are successfully minimizing discharges of OP pesticides from rice fields.

NAWQA data also suggest that DDE concentrations in the Colusa Basin Drain were 2-100 times higher than other sample sites in the Sacramento River watershed (Domagalski et al., 2000). Although DDE was detected in the Knights Landing Ridge Cut and Willow Slough Bypass, only 3 of 12 samples had detectable levels.

### Temporal Patterns

There was no seasonal peak in concentrations during or following the rice pesticide application period (spring) or rice field draining period.

Diuron was detected in April and June. Methomyl was detected in April, chlorpyrifos in June, diazinon in January, and DDE in June and August. The finding that DDE was detected while DDT was not indicates that the source of this legacy pesticide is soil residue rather than illicit uses.

### Conceptual Model

The pesticides detected in west-side tributaries likely come from current, legal uses on farmland or from soil in the case of legacy pesticides such as DDE. While DDE was detected in one sediment sample, all other pesticides were below detection limits in all other sediment samples. Diuron, a carbamate pesticide used on a variety of crops, was detected more often and at more sites than any other pesticide.

Sinks or losses of pesticides include volatilization, degradation, trapping in local soil, and biouptake. The dominant loss mechanism is likely degradation for OPs and sedimentation for OCs. Carbamate pesticides could be reduced by both mechanisms at equivalent rates.

## Salinity

Salinity was measured monthly in the field as electro-conductivity (EC), and in lab samples as TDS. The pattern of EC and TDS consistently indicated that the agricultural drains had relatively higher salinity while the floodwaters and creeks had relatively lower salinity.

### Spatial Patterns

The agricultural drains, Knights Landing Ridge Cut and Willow Slough Bypass had the highest EC levels of all 12 sites and were the only two sites that on average exceeded the potentially applicable EC and TDS criteria. The highest average EC, at the Willow Slough Bypass, was 920 umhos/cm, while the most downstream site, the Toe Drain, averaged less than 500 umhos/cm. These readings are similar to and consistent with salinity levels measured previously by others (Domagalski and Dileanis, 2000; Schemel et al., 2002).

In-Bypass salinity increases downstream through Tule Canal, but salinity at the farthest downstream site is lower than all other contributing sites except for the floodwaters. The source of diluting water is unknown.

Based on conductivity measurements and permitted dry weather flow rates for the Cities of Woodland and Davis wastewater treatment facilities, approximately 25 million pounds of dissolved solids (i.e., TDS) are discharged *into* the Bypass during the dry season (May-November). Based on measurements of TDS and flow rate at Lisbon Weir in the Toe Drain, approximately 40 million pounds of TDS were discharged *from* the Bypass during the same period.

## Temporal Patterns

Floodwaters had the lowest EC levels of all sites. Dry season EC readings were higher on average for each site than wet season readings.

Floodwaters likely flush out any salts that accumulate over time in the Bypass. There is no evidence in model simulations, soil studies, or agricultural production assessments to indicate that salts are accumulating in the Bypass over time.

## Conceptual Model

Possible sources of salts to local wastewater treatment plants include:

- Water supply (deep groundwater aquifer pumping),
- Water softeners,
- Municipal wastewater treatment chemicals, and
- Indoor water use (chemicals, cleansers, food, etc.).

An assessment of salt (as chloride) sources to municipal treatment plants in the Santa Clarita Valley area (LACSD, 2002) produced the pie chart shown in Figure 15. It is assumed that contributions within the City's of Woodland and Davis would be distributed similarly.

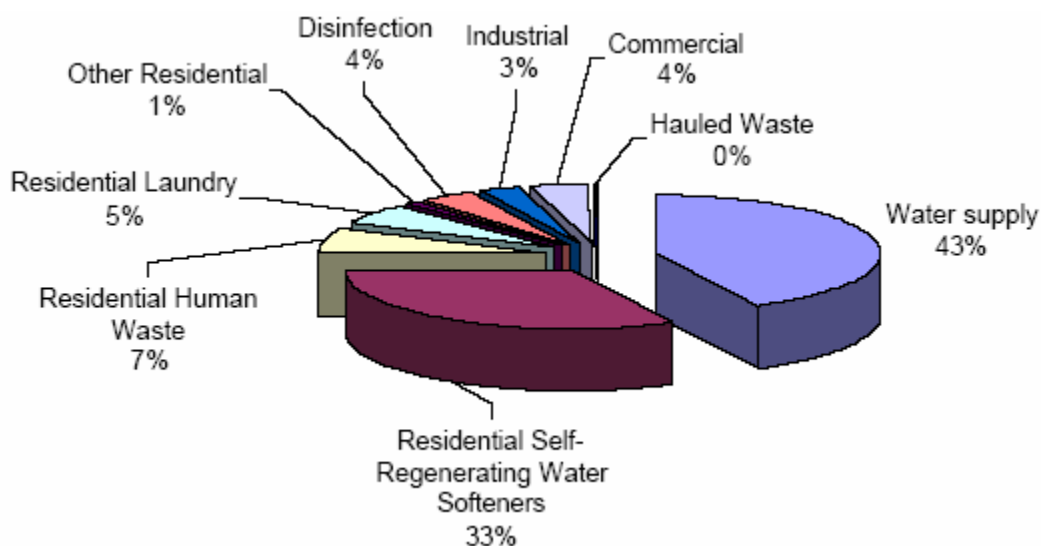


Figure 15. Breakdown of sources of chloride to municipal treatment plants in the Santa Clarita Valley area.

Possible sources of salts in rural tributaries and agricultural drains include:

- Water supply from deep groundwater aquifer pumping,
- Leaching and ex-filtration of groundwater,
- Atmospheric deposition,

- Pesticides and fertilizers, and
- Salt water intrusion.

Evapotranspiration tends to increase salinity as well, although this process is not a source of salts.

The only potential sink identified for salts is sequestration in local soil. Because of the intensive irrigation re-use of water in the Bypass, a large proportion of the salt entering the Bypass during the dry season likely accumulates temporarily in local plant material and soil. However, this loss mechanism is likely insignificant compared to the amount flushed out to the Delta during annual flood events.

## Total Suspended Solids

TSS was monitored primarily to consider the potential for transport of sediment-bound POCs.

### Spatial Patterns

The agricultural drains, Knights Landing Ridge Cut and Willow Slough Bypass had among the highest TSS concentrations while Putah and Cache Creeks had the lowest TSS concentrations. This finding is expected, recognizing that the Creeks both have dams and settling basins that trap large amounts of sediment. In-Bypass sites had TSS concentrations only slightly lower than the agricultural drain sites. Overall the concentrations are slightly lower than suspended particulate matter measured previously by Schemel et al. (2002).

### Temporal Patterns

In-Bypass and west-side tributaries had higher TSS concentrations during the wet season, while agricultural drains had higher TSS concentrations during the dry season. In neither Cache Creek nor Willow Slough Bypass did TSS concentrations correlate with flow rate.

### Conceptual Model

Dams and settling basins in the City of Davis and UC Davis campus and in the two main Creeks appear to regulate sediment loads entering the Bypass such that concentrations are not significantly higher in any season or during higher flows.

Erosion and deposition of sediment along the Bypass is not routinely measured but reportedly occurs in various areas. Other than in ditches and near Fremont Weir, sediment deposition does not appear problematic in the Bypass. Scour is observable from high spots like internal levee roads and in the northeast corner of the Bypass.

## Prioritization of POCs

The POCs can be prioritized for planning purposes. The prioritization scheme employed is as follows:

- High Priority – These pollutants exceed accepted criteria often and in multiple locations or are important to stakeholders for various reasons. These highest-priority pollutants should be dealt with expeditiously with appropriate control measures or other means.

- Medium Priority – These pollutants occasionally exceeded accepted criteria. These pollutants will continue to be listed as POCs and an implementation plan will be included but will not be the focus of near-term activities.
- Low Priority – Monitoring data do not indicate that these pollutants ever exceed accepted criteria. These pollutants will no longer be classified as POCs. No implementation plan is provided for these lowest-priority pollutants.

Based on the information presented above, The POCs are prioritized as shown in Table 10. Implementation plans for high and medium priority POCs are included in the final section of this report.

**Table 10. Prioritization of POCs for the Yolo Bypass Water Quality Management Plan.**

POC	Priority		
	High	Medium	Low
<b>Bacteria</b>	X		
Total coliform			
Fecal coliform			
E. coli			
<b>Boron</b>	X		
<b>Metals</b>			
Aluminum	X		
Chromium			X
Copper			X
Lead			X
Mercury	X		
Selenium			X
<b>Nitrate</b>			X
<b>Organic Carbon</b>		X	
Total organic carbon			
Dissolved organic carbon			
<b>Pesticides and Herbicides</b>			
OCs (DDE and DDT)		X	
OPs (Chlorpyrifos and Diazinon)		X	
Carbamates (Diuron and Methomyl)			X
<b>Salinity</b>	X		
<b>Total Suspended Solids (TSS)</b>			X

# POTENTIAL CONTROL MEASURES FOR HIGH AND MEDIUM PRIORITY POCs

Potentially feasible control measures were identified prior to deciding how to address the POCs. Potential options for addressing the high and medium priority POCs fall into three main categories:

- Implement control measures;
- Continue monitoring and undertake special studies; and
- Pursue development of a site-specific objective or a change in the designated beneficial uses through a Use Attainability Analysis.

The focus of this section is to identify and quantify to the extent practicable potential control measures to implement. Control measures are defined as structures, activities, management practices, or processes that may minimize pollutant loads to the Yolo Bypass. Best Management Practices (BMPs) are control measure activities recognized to minimize pollutant loads in the most effective, efficient manner. However, the term “best” is not meant to imply that such practices are the only effective and efficient way to minimize pollutant loads. The term “control measure” is used to represent any activity or structural device used to control the discharge of POCs to the Bypass. In general, BMPs traditionally apply to agricultural non-point sources of pollution and urban stormwater while control measures are often associated with point sources of pollution such as POTW effluent.

Control measures that could potentially be used to address at least one of the POCs are listed in Table 11. They are generally in order of upstream/source control to downstream/discharge control. Each control measure listed in this table is described in its own section, following a standard format:

- POCs addressed;
- Description;
- Benefits;
- Costs; and
- Other considerations.

Costs and benefits are quantified to the extent practicable and generally in terms of order-of-magnitude estimates. Information on past, present, and future planned implementation of these control measures is also provided, where known. This section was adapted from a technical memorandum reviewed previously by stakeholders (Appendix 7).

Table 11. Summary table of control measures and the POCs that each addresses, as described in this section.

BMP or Control Measure		POCs Addressed						
#	Name	Aluminum	Bacteria	Boron	Mercury	Org. C	Pesti- cides	Salinity
<b>1</b>	<b>Conduct General Outreach and Education</b>		X		X	X	X	X
<b>2</b>	<b>Reduce Local Groundwater Use</b>							
2a	Develop Alternative Water Supplies			X			?	X
2b	Reduce Urban Water Demand			?				?
<b>3</b>	<b>Reduce POTW Influent Loads</b>							
3a	Encourage Alternatives to Conventional Water Softeners							X
3b	Outreach on Proper Operation of Water Softeners							X
3c	Conduct Mercury-specific Outreach and Education				X			
3d	Enhance Industrial Pretreatment	?			?		?	?
<b>4</b>	<b>Enhance POTW Treatment</b>							
4a	Install Tertiary Treatment	?	X		?	?	?	
4b	Install Microfiltration – Reverse Osmosis	X		X	X			X
<b>5</b>	<b>Improve Urban Storm Water Management</b>							
5a	Minimize Effects of New Development		X			X	X	
5b	Outreach to Minimize Stormwater Impacts	X	X	?	X	X	X	?
<b>6</b>	<b>Improve Rural Land and Water Management</b>							
6a	Construct or Improve Settling Basins	X			X		X	
6b	Enhance IPM Programs						X	
6c	Enhance Irrigation Water Management						X	X
6d	Optimize Pesticide Applications						X	
6e	Restrict or Change Pesticide Use						X	
6f	Minimize Erosion and Sediment Transport to Waterways	X	X		X	X	X	
6g	Remove or Stabilize Mine Waste				X			
<b>7</b>	<b>Manage Water Resources for Water Quality Benefits</b>							
7a	Minimize POTW Discharges to the Bypass	X	?	X	?			X
7b	Manage Water Use in Bypass Wetlands	X	?	?	?	X	X	?
7b	Alter Inter-basin Water Transfers		?	X	?	?	?	X

"X" indicates some benefits *likely* could be realized by applying this control measure in the watershed.

"?" indicates some potential *benefits or detriments* could be realized by applying this control measure in the watershed.

# Conduct General Outreach and Education

*POCs addressed: bacteria, mercury, organic carbon, pesticides, salinity*

## *Description*

General outreach efforts that could be considered include: 1) post information on web sites maintained by municipalities and environmental organizations; 2) develop fact sheets for dissemination to the public; 3) utilize press releases at appropriate times (e.g., Earth Day); 4) prepare and give PowerPoint presentations at appropriate venues; and 5) enhance communication and collaboration among agencies and other authorities that manage water resources affecting the Bypass. These activities improve the public's general awareness of local water quality issues impacted by their actions. Pollutant-specific outreach is addressed separately in this memo and would overlap considerably with this control measure.

An additional outreach activity is to inform farm workers and recreational visitors in the Bypass that bacteria levels are high to discourage swimming. Outreach could be conducted by distributing informational fliers or posting notices at potential swimming areas.

Another outreach activity could be to discourage the consumption of fish high in mercury. However, although the state has data on methylmercury in small fish in the Bypass, it has no information on sizes and species consumed by people. A possible useful activity would be to collect data on species targeted by people and, if the levels are above recommended levels, post notices at popular fishing sites.

## *Benefits*

Outreach and education provide relevant information to people regarding the condition of their environment, the impacts that such conditions may have on them, the impacts they may have on the environment, and options for how to change their practices. Outreach can be an effective means of pollutant reduction and risk reduction for humans. Education provides the foundation for outreach, while also encouraging decision-makers and the people they serve to implement additional control measures.

Focused interactions among responsible authorities improve efficiency and consistent understanding of responsibilities for protecting water quality.

## *Costs*

Effective public outreach campaigns for municipalities the size of Davis and Woodland would cost on the order of \$100,000 per year (Elzufon, 2000). Agency collaboration activities require staff time, but presumably are balanced by improved operating efficiency. Outreach to potential swimmers in the Bypass could be accomplished through fliers distributed to farm workers and notices on message boards at the Yolo Basin Wildlife Area and at other areas where Bypass waters are accessible to farm workers and to the public.

## *Other Considerations*

While outreach and education can be fairly effective in comparison to the cost, it does not usually solve a water quality issue on its own. In addition, such campaigns take time to change the behavior of the general population. However, it remains an important element of any management plan and should not be overlooked. More focused outreach activities are described as components of other control measures.

## Reduce Local Groundwater Use

Municipalities and agriculture within and around Yolo County rely on local groundwater resources as a water supply for municipal and irrigation uses. Groundwater in the area is known to contain high levels of salinity and boron. Therefore, by using groundwater as a source of water supply, municipal discharges and irrigation return flows automatically contain higher levels of such constituents. Consequently, one control measure to reduce such inputs would be to reduce the use and reliance on high salinity groundwater by developing other water sources or by reducing demand.

### Improve Source Water Quality

*POCs addressed: boron, salinity*

#### *Description*

Typical salinity levels measured in City of Woodland wells (LWA, 2003; pers. comm. Christine Engel, City of Woodland to S. McCord, 3/5/05) are:

- Supply wells = 900-1100 umhos/cm
- POTW influent = 1650-2000 umhos/cm

Based on these data, municipal uses appear to increase salinity by 500-1000 umhos/cm. Lower hardness supply water should result in a smaller decrease in salinity as softener salts can be dosed less and soaps work better.

Recognizing that groundwater is the dominant source of high hardness and salinity in irrigation tailwater and POTW effluent, reducing the flow from that source by developing alternative water sources is a potential solution. Alternative sources are described here.

- Sacramento River – Sacramento River water<sup>10</sup> has an average conductivity of 140 umhos/cm.
- Deep aquifer groundwater wells that are less saline – such wells in the City of Davis produce water that has an average conductivity of 550 umhos/cm.

Installing deep aquifer wells as a means to reduce salinity in the UC Davis campus wastewater is not an option because all domestic wells serving the campus are already in the deep aquifer.

#### *Benefits*

Based on the salinity levels given above, POTW influent EC would be in the range of 700-1600 umhos/cm if Sacramento River water were part of the supply source, depending on the blend of supplies that could be provided. As a result, wastewater effluent would be considerably lower in salinity and would therefore not be of concern for agricultural or municipal uses of the effluent.

The City of Davis and UC Davis campus have already tapped into deeper wells to try and reduce the salinity of their water supply. However, the use of such wells does not solve the salinity issues for the municipal wastewater dischargers. For example, POTW influent EC would be in the range of 1100-1600 umhos/cm if deeper well water were used as a supply source, depending on the blend of supplies that could be provided.

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<sup>10</sup> Based on measurements at Veteran's Bridge reported in the Coordinated Monitoring Program's 2003 Annual Report, available on-line at <http://www.srcsd.com/pdf/rpt-cmp-03.pdf>.

Delivering better quality supply water would also benefit users by improving drinking water taste and reducing uses of soaps and water softener salts.

### *Costs*

In order to obtain a surface water supply, the municipalities must go through the State Water Resources Control Board and obtain an appropriative right, or contract with other entities that currently have surface water rights. In either case, the Cities, UC Davis, and agricultural water suppliers would incur costs associated with this process. In addition, surface water supplies are likely to cost more per acre foot than the cost that is currently associated with groundwater pumping costs.

Installation costs for new wells tapping the deep aquifer cost on the order of \$1.2 million (pers. comm., David Phillips, UC Davis, to S. McCord, 2/10/05). The cost of installing deep aquifer wells for agricultural groundwater users may not be practical.

### *Other Considerations*

Besides a potential cost increase, the ability to successfully obtain rights to a surface water source for water supply is not guaranteed. As the population in California continues to grow, there are additional demands on California's surface water supplies. As a result, obtaining surface water rights is a competitive process that offers no guarantees. The Cities of Davis and Woodland have had applications for Sacramento River water rights pending before the State Board for over five years.

Another consideration is the actual need for municipalities to obtain alternative sources of water in order to reduce salinity in the effluent. Currently, the primary beneficial uses that are driving the issue are municipal and agricultural uses. The DHS secondary drinking water standard for municipal uses is a minimum of 900 umhos/cm<sup>11</sup>. The most conservative number currently used for agriculture is 700 umhos/cm. The 900 umhos/cm for municipal uses applies to Putah Creek and therefore the University of California, Davis' discharged effluent. It is based on the secondary maximum contaminant level (MCL), which is a consumer acceptance taste and odor standard and not a public health level. DHS commonly approves drinking water supplies that exceed this level. The Bypass is not designated as having a beneficial use of municipal drinking water supply.

The 700 umhos/cm level for agriculture is subject to even further questions of applicability in this area. The standard comes from a United Nations study that recommends water quality goals and guidelines. The 700 umhos/cm is the most conservative recommended standard for the most salt sensitive crops in all climates throughout the world, including arid and desert regions. It does not account for natural conditions, actual crops grown or rainfall. As a result, studies are currently underway to determine what may be an appropriate standard for the Yolo Bypass area considering all the necessary factors. The studies are being conducted by researchers at the University of California, Davis. In addition to these studies, the local agricultural community is not convinced that 700 umhos/cm is necessary for the crops grown in and near the Bypass. The agricultural community appears to be more concerned with potentially losing the irrigation water created from these discharges than with receiving irrigation water with a slightly higher level of salinity. Average salinity in the Bypass is already below 700 umhos/cm.

Residential development in Lake County may develop surface water storage. These reservoirs could provide some additional relatively low salinity water to Cache Creek during the dry season.

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<sup>11</sup> The secondary drinking water standards for EC can be found in Table 64449-B of Title 22, Div 4, Chap 15, Article 16 and for Specific Conductance, in micromhos: 900 (Recommended), 1,600 (Upper Limit), 2,200 (Short Term).

## Reduce Urban Water Demand

*POCs addressed: boron, salinity*

### *Description*

Groundwater pumping for urban areas could be reduced by reducing water demand directly or by expanding local water reuse to effectively reduce demand for new water. Potentially effective tools include outreach/education, installation of water meters and water use fees based on use rates, installation of improved water use technologies, and enforcement of landscape water use standards.

### *Benefits*

Salt and boron loads introduced from groundwater aquifers could be reduced by reducing groundwater use and subsequent discharge.

### *Costs*

Minimal costs to municipalities would be incurred for conducting outreach and education to reduce water demand.

Residents can purchase improved technologies for plumbing fixtures, washing machines, irrigation systems, and water heaters. Industrial and commercial units can install low-flow toilets and high efficiency cooling towers. Costs associated with designing, constructing and operating local water reuse systems are undetermined.

Increased energy efficiency tends to balance costs of irrigation controller systems and indoor technologies (DWR, 1998). Similarly, WWTP treatment costs could be slightly reduced for the lower influent flows.

### *Other Considerations*

The net result of reducing water use would be to reduce pollutant *loads* to local waterways. However, the salt *concentration* in POTW influent would be slightly higher as the slightly lower load of salinity added in the service area would be concentrated in proportionally less influent water. Consequently, the advantage of increased water efficiency may not improve water quality. In addition, the loss of effluent may negatively impact the agricultural community that relies upon the effluent discharge for irrigation purposes. Many of the available water conservation measures have already been promoted through rebate programs and are unlikely to result in large incremental reductions in water use.

Local agencies are required by the 1990 Water Conservation in Landscaping Act to enforce ordinances intended to promote water-efficient designs. The Act's requirements apply to landscapes greater than 2,500 square feet in area. Water used for landscape irrigation is an indirect and probably a miniscule load to the nearest water body.

DWR (2000) deferred implementing regional scale urban water conservation options, reasoning that no significant depletion reductions were attainable.

## Reduce POTW Influent Loads

POTW influent loads of some POCs can be reduced by focusing on the major sources of those POCs. This section describes several control measures that could be implemented within POTW service areas to reduce influent POC loads. These measures could be expected to reduce POTW effluent loads.

## Encourage Alternatives to Conventional Water Softeners

*POCs addressed: salinity*

### *Description*

The typical self-regenerating water softener operates by removing the ions contributing to hardness with an ion exchange resin column. Over time, the column becomes saturated with the hardness ions, and it becomes necessary to replenish the sodium ions via regeneration. By passing a strong brine solution (about 3 pounds of salt per gallon, equivalent to approximately 360,000 mg/L) through the bed, the hardness ions are overwhelmed by the strength of the sodium ions and are driven off the bed. At the end of the process, the waste brine is discharged to the sanitary sewer. The waste brine is a source of salts discharged to POTWs.

Salts can be reduced in POTW influent by implementing tighter controls for water softeners, and perhaps new pre-treatment technology for some industrial equipment (e.g., boiler feed water). Alternatives to self-generating water softeners include portable tank exchange services, magnetic / electronic / catalytic water conditioners, reverse osmosis, carbon filtration, and distillation. Similar alternatives to conventional softeners could also be applied at wellheads rather than at individual buildings.

### *Benefits*

UCD has estimated that a 3-10% reduction in POTW influent salinity may be possible by incorporating advanced technology for boiler feed water and other major water uses (pers. comm., D. Phillips).

It is estimated that the Cities of Davis and Woodland combined may be able to reduce total salt loads to the Bypass by approximately 5,000 pounds per day if 40% of the households with self-generating water softeners would replace such systems. This is assuming that there are 40,000 households in Davis and Woodland combined and that 20% of households have self-regenerating water softeners.

### *Costs*

Rebates, credits and buy-back programs can be used to promote alternatives to conventional water softeners. Assuming 40,000 households in Davis and Woodland combined, 20% of households have self-regenerating water softeners, 40% of those households would decide to participate in the program, and \$800 for providing an alternative softener system, total costs for implementing a water softener replacement program would be approximately \$2.5 million if it is assumed that a \$800 rebate is given to 40% of the households with self-regenerating water softeners. Costs to homeowners would be on the order of \$3000 per whole-house unit without rebate.

### *Other Considerations*

Brine produced by softening all potable water and disposal of brine from wellheads distributed throughout the municipalities would be problematic.

Municipalities can ban water softeners for new development only under certain limited circumstances. Municipalities cannot legally ban existing water softeners, but they may be able to provide incentives for alternatives. However, alternatives can be expensive to purchase and maintain. Any brine, precipitate or filters must be disposed rather than discharged back to the sanitary sewer.

## Outreach on Proper Operation of Water Softeners

*POCs addressed: salinity*

### *Description*

For wastewater dischargers into the Yolo Bypass, salinity issues are of the greatest concern. A large source of salinity in wastewater comes from self-generating water softeners. Outreach and education to members of the public regarding the impact of inefficient water softeners and instructions on efficient use could help to reduce salt loads.

### *Benefits*

If only 40% of the households participated in a program to increase water softener efficiency (assuming 40,000 households in Davis and Woodland combined and 20% of the households having self-regenerating water softeners) each of those participating systems could be made 10% more efficient, total salt loads to the Bypass could be reduced by approximately 500 pounds per day.

### *Costs*

Effective public outreach campaigns for municipalities the size of Davis and Woodland would cost on the order of \$100,000 per year (Elzufon, 2000). Such a campaign could incorporate multiple elements besides water softeners.

### *Other Considerations*

None identified.

## Conduct Mercury-specific Outreach and Education

*POCs addressed: mercury*

### *Description*

Mercury's unique chemical characteristics, sources and environmental impacts may require special control measures. Potential control strategies identified for mercury are listed in Table 12.

Table 12. Potential Mercury Source Control Strategies.

Potential Source	Control Strategy
Dentists	Business outreach with BMPs; regulate
Household products (thermometers, contact lens solution, fluorescent light bulbs)	Outreach to pharmacies; public thermometer collection program; fluorescent light bulb exchange program
Hospitals; laboratories	Outreach; sewer line cleaning
Laundry	Promote graywater systems

### *Benefits*

Both POTW effluent and urban stormwater would benefit from these outreach activities. It is difficult to quantify the potential benefit that municipalities in the Bypass may obtain by implementing the control strategies above. However, examples from other POTWs may provide a useful illustration of potential benefits.

First, the City of Palo Alto quantified its annual influent loading of mercury by source (Elzufon, 2000). These potentially controllable sources represented approximately 30% of the total influent mercury load. Assuming that these loads could be reduced by approximately 50%, the potential total influent load reduction by implementing all of these control strategies would be on the order of 15%. The resulting reduction in effluent load would be 0-15%. The low end of this range is in recognition that a reduction in influent mercury load does not necessarily translate into reduction in effluent load.

Second, the Sacramento Regional County Sanitation District (SRCSD) has implemented an effective mercury reduction program that could be mimicked in the Yolo Bypass watershed<sup>12</sup>. SRCSD's residential mercury outreach and collection efforts have resulted in the removal of an estimated 18.5 pounds of elemental mercury and approximately 192 pounds of mercury and mercury-containing products over the past two years. Scaling these values by the proportional populations (~100,000 in the Davis and Woodland communities versus ~1 million in the Sacramento service area), local outreach efforts would result in approximately 2 pounds of elemental mercury being collected. Considering that conventional wastewater treatment facilities remove on the order of 90% of influent mercury, the load reduction to the Bypass would be on the order of 0.2 pounds.

### *Costs*

Costs to POTWs for implementing these control strategies are primarily associated with staff time needed for interact with businesses such as dentists, pharmacies and hospitals that may not be regulated currently. Public outreach activities would require educational materials and staff resources as well. There may also be some costs associated with monitoring the collection system to better determine the amount of mercury that is entering the POTW from the various areas of the collection system.

### *Other Considerations*

The City of Woodland is currently surveying local dentists to determine what mercury reduction measures are used currently.

As described later, the cities of Davis and Woodland have been asked to characterize the methylmercury in their wastewater effluents. If elevated, the cities might be required to implement programs to reduce the methylmercury in the effluent and that might provide impetus for outreach and education.

## **Enhance Industrial Pretreatment**

*POCs addressed: aluminum, mercury, pesticides, salinity*

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<sup>12</sup> See the "Be Mercury Free" website at <http://www.bemercuryfree.net/index.html>.

### *Description*

Pretreatment programs for industries such as vehicle service facilities, printers, and commercial car washes can reduce metals loads to sewers. Food processing industries often discharge high salt loads that could be reduced.

### *Benefits*

Load reductions of 30-99% for many heavy metals (e.g., copper, mercury, lead, silver, zinc) can be achieved by such facilities. The resulting percent reduction in POTW influent depends on the relative contribution of industries.

### *Costs*

Effective pretreatment programs for municipalities the size of Davis and Woodland cost on the order of \$50,000 per year (Elzefon, 2000).

### *Other Considerations*

The City of Davis, in particular, is a residential community with a small industrial base. The industrial pretreatment programs for both the Cities of Woodland and Davis prioritize BOD, solids, fats, oil, and grease for pretreatment. Local limits for City of Woodland's four Significant Industrial Users include the pollutants of concern mercury and DDT. The City of Davis and UC Davis campus do not have local limits.

Industries that tend to produce high-salinity wastewater include, for example, textiles, food processors, and petroleum refineries. None of these or similar industries exist on a large scale in the watershed. Thus, industrial pretreatment local limits for salts would have negligible benefits on salinity in POTW effluent.

As described later, the cities of Davis and Woodland have been asked to characterize the methylmercury in their wastewater effluents. If elevated, the cities might be required to implement programs to reduce the methylmercury in the effluent and that might provide impetus for additional industrial pretreatment control measures.

## **Enhance POTW Treatment**

Three advanced wastewater treatment technologies are discussed in this section:

- Tertiary treatment;
- Carbon adsorption; and
- Microfiltration – reverse osmosis.

Other technologies such as nitrification-denitrification and ultraviolet disinfection would not address high or medium priority POCs.

### **Install Tertiary Treatment**

*POCs addressed: aluminum, bacteria, mercury, organic carbon, pesticides*

### *Description*

Primary treatment of wastewater reduces oils, grease, fats, sand, grit, and coarse (settleable) solids. Secondary treatment of wastewater means biological oxidation to reduce further BOD and suspended

solids concentrations. Tertiary treatment of wastewater provides additional treatment for more specific water quality benefits. Common tertiary treatment processes include filtration, and polishing wetlands.

#### *Benefits*

Organic pesticides and inorganic compounds such as nitrogen, sulfides, and heavy metals are generally reduced to some degree by tertiary treatment.

#### *Costs*

The City of Woodland estimated that total 20-year life-cycle costs to upgrade to tertiary treatment would be approximately \$20 million (ECO:LOGIC Engineering, 2003).

The UC Davis campus wastewater treatment facility operates a tertiary treatment facility. The filters cost approximately \$1.8 million for the current 2.5 MGD design flow rate (pers. comm., David Phillips, UC Davis, to S. McCord, 2/10/05). Operation and maintenance costs will result in similar life-cycle costs as for the City of Woodland.

#### *Other Considerations*

Because tertiary treatment processes tend to target specific pollutants, (e.g., BOD, TSS, bacteria) systems cannot be expected to reduce effluent concentrations of other pollutants.

### **Install Microfiltration – Reverse Osmosis**

*POCs addressed: aluminum, boron, mercury, salinity*

#### *Description*

Microfiltration following tertiary treatment produces effluent suitable as a feed source for reverse osmosis. Reverse osmosis (RO) is a water treatment technology that utilizes membrane filters to remove dissolved substances. This control measure only addresses constituents that were not removed by tertiary treatment. Water is separated from dissolved salts in solution by filtering through a semi-permeable membrane at a pressure greater than the osmotic pressure caused by the dissolved salts in the wastewater.

#### *Benefits*

High-salinity effluent can be treated to reduce salinity as well as other particulate and dissolved compounds. An RO system could be operated at moderate performance levels to simply improve conditions, or at maximum efficiency to produce potable water.

#### *Costs*

The major costs associated with RO systems include construction, operation, and brine disposal. Approximate costs for Florida (United States Navy, 2005) are:

- Construction (\$mil/MGD capacity): 1.4-2.1
- Operation and maintenance (\$/million gallons of production): 1,060-1,550

Total costs approximated for a 10 MGD facility with a 20-year life cycle and not discounted would be \$5-7 million per year. A deep well in which to inject the brine would cost on the order of \$1 million.

The City of Woodland estimated that total 20-year life-cycle costs to treat approximately half of its wastewater through RO filters and evaporate the brine would be approximately \$110 million (ECO:LOGIC Engineering, 2003).

### *Other Considerations*

The major constraints to installing and operating RO systems include:

- Disposal of a continuous waste stream of RO brine (the process water that does not pass through the filters) is especially problematic in inland areas. Brine could be injected into deep wells. Potential impacts on groundwater aquifers are unknown. Piping or otherwise transporting brine to the ocean is not perceived to be a realistic option;
- The high capital investment should be preceded by information to show that high salinity effluent is problematic and caused by wastewater effluent;
- Effluent discharges would be reduced by approximately 20%, decreasing water supply available to current water users in the Bypass; and
- Operation of RO systems requires higher energy for pressuring the process water.

Because the major water supplies for the Cities of Davis and Woodland are groundwater, wells are decentralized. A separate piping system to remove and treat the brine from each of the dozens of wells would require an entirely new piping system. Brine injection wells would each cost on the order of \$1 million to construct and operate.

## **Improve Urban Storm Water Management**

Water quality studies have shown impacts on receiving water caused by stormwater runoff from impervious surfaces. Pollutants associated with residential, commercial and industrial activities in a watershed include sediment, fertilizers, pesticides, other chemicals, paints, waste oil, other vehicle fluids, petroleum hydrocarbons, heavy metals, and coliform from human and animal wastes. Stormwater runoff that comes in contact with these pollutants are transported quickly and efficiently to and through the stormwater sewer system and discharged directly to receiving waters. In addition, stormwater runoff rates and quantity may significantly increase as a result of impervious surfaces cause by new development.

Stormwater discharges are regulated in California by NPDES permits. Separate permit programs relevant to the local Yolo Bypass watershed are described here.

- The Cities of Davis, Woodland, and West Sacramento, the County of Yolo and the UC Davis campus are regulated under Phase II of the NPDES General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems. Their stormwater management programs will be fully implemented by 2008.
- Construction sites disturbing greater than 1 acre of land are required to comply with the statewide NPDES General Permit for Discharges of Storm Water Runoff Associated with Construction Activity.
- Qualifying industrial facilities are required to comply with the statewide NPDES Industrial Storm Water General Permit. The State Board web site<sup>13</sup> indicates that two facilities in Davis, 6 on the UC

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<sup>13</sup> Site accessed on January 19, 2004 at <http://swrcbnt3.swrcb.ca.gov/stormwater/search/IndSearch.asp>.

Davis campus, 28 in Woodland, and 3 in Winters actively participate in the industrial stormwater permit program.

Permittees regulated by these stormwater programs are required to reduce pollutant loads in their discharges to the maximum extent practicable, and eventually to the point that water quality objectives are achieved in the receiving waters. Specific activities expected to provide the greatest water quality benefits to the Bypass are described in this section.

Costs for municipal stormwater programs are difficult to distinguish from normal practices. A recent survey by the California Stormwater Quality Association found current costs ranging from \$18 to \$48 per household per year (pers. comm., Brian Currier, CSUS, to S. McCord, 3/9/05). Descriptions of costs associated with specific program elements described in this section are provided only for initial guidance.

## **Minimize Effects of New Development**

*POCs addressed: bacteria, organic carbon, pesticides*

### *Description*

The Small MS4 General Permit requires municipalities to develop, implement and enforce a program for stormwater runoff from new development and redevelopment projects that result in land disturbance of one acre or more to prevent and minimize water quality impacts. The program must include a plan to implement site-appropriate and cost-effective treatment and source BMPs and ensure long-term operation and maintenance of such BMPs. The Small MS4 General Permit requires the City and UC Davis to adopt a set of design standards for certain development categories.

### *Benefits*

Impacts to water quality and the physical and biological characteristics of an aquatic habitat caused by new development can be minimized through implementing post-construction stormwater BMPs. BMP handbooks such as those available from the California Stormwater Quality Association<sup>14</sup> provide some measure of removal efficiencies for various BMPs. Removal efficiencies depend greatly on site-specific conditions.

### *Costs*

Costs for developers to incorporate stormwater BMPs are difficult to distinguish from normal practices. Revising design standards, training staff, revising municipal code, and inspecting and maintaining facilities increase costs for municipalities. Additional land requirements for structural BMPs require more land. A recent survey by the California Stormwater Quality Association may have benchmark costs available soon.

### *Other Considerations*

None identified.

## **Outreach to Minimize Stormwater Impacts**

*POCs addressed: aluminum, bacteria, boron, mercury, organic carbon, pesticides, salinity*

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<sup>14</sup> Available on-line at <http://www.cabmphandbooks.org/>.

### *Description*

Outreach in urban areas is required for permitted municipal stormwater management programs. Municipal stormwater outreach activities that could be promoted and the POCs that they address are identified in Table 13.

**Table 13. Public outreach activities to address POCs.**

<b>Activity</b>	<b>POCs Addressed</b>
Promote use of “doggy bags”	Bacteria
Announce bulk waste collection dates	Organic carbon
Announce hazardous waste collection events	Metals, pesticides
Conduct general stormwater awareness campaigns	All
Efficient operation of lawn irrigation systems	Boron, pesticides, salinity
Promote IPM programs and appropriate residential pesticide applications	Pesticides
Provide containerized green waste pick-up	Organic carbon

### *Benefits*

The benefits of stormwater-related outreach are difficult to quantify because they depending on several factors such as current level of awareness, the design and timing of the campaign, and the imprecise relationship between the polluting activities and water quality impacts.

Several of the activities described are already practiced in the Cities of Davis and Woodland, so the additional benefit derived from increased awareness are uncertain.

### *Costs*

Effective public outreach campaigns for municipalities the size of Davis and Woodland would cost on the order of \$100,000 per year (Elzufon, 2000).

### *Other Considerations*

Green waste containers would be most useful in the City of Woodland, and such a program is being implemented in the new portions of the City. The remainder of the City will be phased into the program. Discharges from the City of Davis are largely captured in stormwater detention ponds, in which organic carbon is not identified as a pollutant of concern.

## **Improve Rural Land and Water Management**

Rural land management focuses on agriculture but also includes other non-point source rural areas.

For agriculture, control measures typically take the form of management practices for crop cultivation, irrigation and pesticide applications. While the Regional Board can not require specific BMPs, they can

require that agricultural and other nonpoint source dischargers implement BMPs if necessary to meet water quality standards. Up until recently, the Regional Board had allowed agricultural dischargers to operate under a waiver of the requirement to file a report of waste discharge. Revisions to the California Water Code forced the Regional Board to rescind the old waiver and adopt a new one that complied with the amended provisions. The new waiver as adopted by the Regional Board requires agricultural dischargers to monitor to assess compliance, implement BMPs to address compliance issues, and eventually to comply with water quality standards. It allows compliance with the waiver provisions through individual or group development of monitoring programs, and if necessary with water quality management plans. It is anticipated that water quality management plans developed in conjunction with the waiver will identify various management practices that are designed to address the pollutant (or pollutants) that is causing a violation of an applicable water quality standard. The development of water quality management plans that are specific to agriculture in the area should be considered to be a control measure. While it is not feasible to identify all of the potential management practices because of the variability in agriculture in and near the Yolo Bypass, several common control measures are identified and discussed here.

Erosion from disturbed land and even open space contribute sediments and their associated water quality impacts. Some control measures in this section apply to non-agricultural lands.

### **Construct or Improve Settling Basins**

*POCs addressed: aluminum, mercury, pesticides*

#### *Description*

Settling basins are essentially a specialized type of treatment wetland. The removal mechanism is simple settling of sediment and other particulate materials. Such material would contain a large proportion of the suspended load of weakly soluble metals and pesticides. Additional opportunities – or lack thereof – for installing new basins or optimizing the sediment removal efficiency of existing basins are as follows:

- The Cache Creek Settling Basin's sediment removal efficiency could be increased by raising the weir height or at least maintained by regularly excavating accumulated sediment.
- The 100-acre UC Davis Arboretum Waterway ("Arboretum") serves as a settling basin for campus runoff. All stormwater runoff from the central campus is routed into the Arboretum. Water collected in the channel largely infiltrates into the local aquifer. During a storm event, water from the Arboretum spills over a weir at the west end and large pumps send the water via pipeline into the South Fork of Putah Creek. Water in this basin could be pumped to and treated at the campus wastewater treatment facility during off-peak periods.

Because Lake Berryessa and Lake Solano trap the vast majority of sediment from the Putah Creek watershed, a settling basin near the mouth of Putah Creek would be redundant and ineffective. Approximately two-thirds of land within the City of Davis drains into retention ponds. The ponds are managed primarily to control floodwaters and maximize removal of particulates before discharging to agricultural drains. Wildlife and vegetation in these ponds are regularly monitored. Excavation of sediments within the Bypass is not necessary because sediment does not appear to be accumulating.

### *Benefits*

Maintaining the Cache Creek Settling Basin at approximately maximum efficiency would remove, on average, an estimated additional 50 pounds per year of total mercury from entering the Bypass, compared to not maintaining the Basin. Potential additional load reductions for pesticides and other metals have not been quantified.

Water quality benefits to Putah Creek and the Delta from treating Arboretum water in the UC Davis campus wastewater treatment facility would be negligible. The primary benefits would be improved water quality in the Arboretum and the potential for local water reuse.

### *Costs*

The lowest-cost alternative is to maintain the existing Cache Creek Settling Basin. Maintenance costs are estimated to be as high as \$15 million<sup>15</sup>, but depend greatly on feasible soil disposal and reuse options.

Planning, design, and construction of the project to process water from the Arboretum Waterway through the campus wastewater treatment facility will cost approximately \$350,000.

### *Other Considerations*

The State of California, acting through DWR, is responsible for maintaining the Cache Creek Settling Basin. The Delta mercury TMDL being developed in 2005 could require maintenance of the basin as a component of the implementation strategy. Local stakeholders could contribute to that activity by lobbying the legislature, sending letters in support of DWR conducting these activities, or helping to secure funding through grants.

An additional study noted later in the management plan calls for measuring sediment accumulation rates in various regions of the Bypass. The results of such a study may identify sediment hot spots on which future erosion control could be focused.

Also noted later in the management plan is that UC Davis facilities engineers are currently planning a project to reroute treated water from the Campus Wastewater Treatment Plant through the Arboretum Waterway. The purpose of the project is to provide a source of fresh water during dry weather to the Arboretum, but a potential consequence is changes in pollutant loads to Putah Creek.

## **Enhance IPM Programs**

*POCs addressed: pesticides*

### *Description*

Integrated pest management (IPM) is “an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment.”<sup>16</sup> To the

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<sup>15</sup> Present-worth cost assuming a 30-year project life cycle, assuming the soil is disposed at the Yolo County landfill.

<sup>16</sup> Taken from UC Davis, Division of Agriculture and Natural Resources website, [www.ipm.ucdavis.edu/IPMPROJECT](http://www.ipm.ucdavis.edu/IPMPROJECT).

extent that IPM programs decrease the use of broad spectrum pesticides, it can be an effective control measure for some pesticides that have been identified as a pollutant of concern.

#### *Benefits*

IPM targets the pests of concern and tries to avoid using broad spectrum pesticides or overuse of pesticides.

#### *Costs*

Costs of implementing an IPM program have not been documented, or were not found through broad research efforts. However, it can be generally assumed that IPM programs may reduce some yields, or increase the cost of crop protection materials since they are more targeted. IPM programs can also be management intensive, requiring labor for monitoring, though this can offset the costs of applying pesticides.

#### *Other Considerations*

IPM may not be appropriate in all circumstances. Occasionally there are wide spread pest infestations that can not be controlled through the use of IPM.

### **Enhance Irrigation Water Management**

*POCs addressed: pesticides, salinity*

#### *Description*

Irrigation water can be managed differently to potentially reduce salinity and pesticide concentrations in tailwater. Recycling water is an efficient process that reuses local water supplies. Adoption of new irrigation technology to reduce applied water would most likely result in a reduction of deep percolation, tailwater runoff, evapotranspiration (ET), or leaching effects. Reductions of deep percolation and tailwater runoff can be achieved by improving irrigation water application and management. ET can be reduced by minimizing irrigating with minimal loss in productivity.

#### *Benefits*

More efficient water use reduces water pumping costs and transaction costs.

Longer holding times would reduce concentrations of degradable pesticides but increase salinity concentrations through evapotranspiration. Shorter holding times would have the opposite effect.

#### *Costs*

Importing additional water to irrigate fields would cost more to deliver. Within the Bypass, the typical scenario would be west-side farms needing to pump from the east-side Tule Canal or Toe Drain.

#### *Other Considerations*

A reduction in irrigation water may further concentrate salt levels in the soil causing greater damage to crops than using more, high salinity irrigation water. When water is high in salinity, one management practice to maintain crop yields is to increase the amount of water used for irrigation in order to ensure that any accumulated salt is leached from the root zone. Leaching could result in less productive soil and consequently reducing water use efficiency.

## Optimize Pesticide Applications

*POCs addressed: pesticides*

### *Description*

Application practices could be optimized to minimize pesticide loads to water by using any or a combination of several methods:

- Use new sprayer technologies (e.g., microsprinklers and Smart Sprayer™);
- Calibrate sprayer equipment more frequently;
- Use unidirectional spray equipment on the outer rows to spray only in toward the crops;
- Schedule irrigation to minimize impacts of irrigation return flows on receiving waters (e.g., do not spray when rain is in the near-term forecast);
- Use drift retardants;
- Target pesticide applications only to areas with infestations; and
- Improve mixing/loading procedures.

In summary, a wide variety of options are available to farmers in response to efforts to reduce runoff of pesticides that are potentially harmful to water quality. Many of these practices are already required by the pesticide label instructions and are considered legal restrictions on the use of the pesticide. Failure to follow pesticide label instructions is punishable in law and is enforced by the County Agricultural Commissioner. Management practices not controlled by pesticide label instructions may vary from grower to grower. However, such practices should be chosen in a manner to minimize the off-site movement of pesticides.

### *Benefits*

Implementing improved pesticide application practices would result in more uniform applications at the most efficient rate. Reduced pesticide application rates would save money and result in less loss to waterways. Pesticide loads to local waterways would decrease by implementing this control measure. Depending on tree size and spacing, total pesticide applied per acre of orchard can be reduced by 10% to 80% (greatest reductions on trees 1-5 years old) compared to conventional sprayers by using technologies such as Smart Sprayer™.

### *Costs*

Additional time and expense would be needed to install upgraded equipment and implement improved practices. No cost figures have been generated. Potential reductions in crop yields caused by reduced pesticide use have not been quantified.

### *Other Considerations*

None noted.

## Restrict or Change Pesticide Use

*POCs addressed: pesticides*

### *Description*

One control measure that is often raised when addressing the issue of pesticides is further restricting (or banning) the use of a specific pesticide. This control measure is currently applied to urban uses of the organophosphate pesticides chlorpyrifos and diazinon.

One alternative to water-soluble organophosphate- and carbamate-based pesticides in fields that drain directly into waterways is pyrethroid-based pesticides. These tend to be less water-soluble, resulting in lower concentrations in irrigation tailwater (Freeman Long et al., 2002). However, there are concerns regarding the sediment toxicity of pyrethroids. If adsorbed to eroded sediments, control measures such as buffer strips or fescue in drains would minimize off-site transport.

An alternative to diuron-based herbicides is Roundup. A Roundup-ready alfalfa is coming to market in 2005. Paraquat, containing gramaxone as its active ingredient, is a contact herbicide rather than a pre-emergent herbicide applied to prevent seed germination. This type of chemical and its application tends to reduce losses to local waterways. Alternatives to methomyl are indoxycarb and glyphosate, which appear to have lower toxicity to aquatic life (pers. comm., Rachel Long, UCD Cooperative Extension, to S. McCord, 2/1/05).

### *Benefits*

In most cases, the elimination of use should eliminate the pesticide of concern from the Bypass.

### *Costs*

While there may be little cost to actually implement a restriction, there will be indirect costs that result from the pesticides elimination. For example, crop yields may decrease due to an increase in pests and disease; the use of alternative pesticides may be more costly for growers; and the research and development costs for replacement products are high.

### *Other Considerations*

In California, the governmental agency with sole jurisdiction to implement such a control measure is the California Department of Pesticide Regulation. Local governmental entities and the Regional Boards do not have the legal authority to restrict the use of pesticides. However, while the Regional Boards do not have authority to restrict use of pesticides, they can restrict the discharge of those pesticides into waters of the state. Such is the case for rice herbicides where there is a prohibition of discharge unless the discharger is following specific practices contained in a management plan approved by the Regional Board. The Rice Commission develops a management plan annually<sup>17</sup> and submits it to the Regional Board for approval. The latest approval occurred on 18 March 2005.

The elimination of some pesticides may result in the increased application of more environmentally harmful pesticides. For example, the organophosphate pesticides (chlorpyrifos and diazinon) are considered to be broad spectrum pesticides that dissipate fairly quickly in water. As the use of these crop protection chemicals becomes more restrictive, growers are turning to alternative pesticides. In some cases, the alternatives are pyrethroids for which little information is available. The pyrethroids do not usually impact water column concentrations but may be more prevalent in the soil since these compounds bond very tightly to soil. Consequently, the pyrethroids may exist in the environment much longer than other

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<sup>17</sup> They recently took over responsibility for this annual plan. Previously the plan was developed by DPR.

pesticides. There is little information available as to the bioavailability of pyrethroids once they adsorb to sediment.

In addition, the elimination of use does not automatically mean that the pesticide will disappear from the environment. There are several pesticides that are creating concern even though they have been banned for a number of decades (e.g., DDT).

## Minimize Erosion and Sediment Transport to Waterways

*POCs addressed: aluminum, bacteria, mercury, organic carbon, pesticides*

### *Description*

Three control measures that minimize erosion and sediment transport from agricultural lands are commonly promoted locally, as described below<sup>18</sup>.

- Double-section design tailwater ponds are designed such that silt-laden irrigation tailwater and storm runoff enters the first pond (narrow trench design) which functions as a sediment trap. Captured silt is easily reincorporated into the field each fall. Nutrient-laden water exits this sediment pond via drop pipe inlet to the second, a recharge/return pond. Nutrients can be removed from tailwater by aquatic and shore plants before release into lower fields, drainage canals, or natural sloughs.
- A grassed waterway/vegetated filter system is a natural or constructed vegetated channel that is shaped and graded to carry surface water at a non-erosive velocity to a stable outlet that spreads the flow of water before it enters a vegetated filter. They can be constructed where water concentrates and gully erosion is a problem.
- A riparian forest buffer is an area of trees and shrubs located adjacent to water bodies. These areas have year-around and seasonal water available. They minimize streambank erosion, provide a wind buffer to adjacent properties, and they provide wildlife habitat.
- Inject polyacrylamide (PAM) into irrigation water to reduce off-site transport of sediment.

Erosion control could be improved for farmland throughout the watershed. For the Willow Slough watershed, a total of 2,440 acres of actively farmed cropland could be converted to tailwater ponds, riparian corridors, or large perennial wetlands (Jones and Stokes, 1996). These low-lying areas represent approximately 3.5% of the active cropland in the watershed.

The major source of mercury to the Bypass is mercury-laden sediments. A large but poorly quantified portion of this sediment is eroded native soil, while more contaminated soils emanate from historical mining areas. Erosion from lands managed by the US Bureau of Land Management will be reduced through appropriate restrictions on livestock grazing, surface mining, and off-road vehicle use (USBLM, 2004).

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<sup>18</sup> These and other control measures are described in the NRCS web site at <http://www.ca.nrcs.usda.gov/programs/buffer.html>. These specific measures were suggested by Arturo Carvajal, USDA/NRCS Water Management Specialist Engineer.

## *Benefits*

A Pilot Program funded by CALFED and conducted by Yolo County RCD found that newly dug traps removed 98% of incoming sediment in the first irrigation (which caused most soil erosion). The percent of sediment captured during the growing season in tailwater ponds studied ranged between 11 and 97%. In the one tailwater pond built in combination with a sediment trap, combined sediment capture was consistently higher, ranging between 46 and 99% (pers. comm., A. Carvajal to S. McCord, 1/24/05). The types and relative proportions of benefits for a given pond depend on location, design, and duration of impoundment.

In tailwater ditches, portable canvas dams slow runoff and collect sediments that may extend the utility life of the sediment traps, which need to be excavated to entrain new sediments. Sediment traps that are properly maintained and built in combination with a tailwater pond sediment collection become more effective and the life of the pond is increased.

Sediment traps and filters also tend to remove bacteria through the processes of filtration and degradation. Removal rates of 95% for total coliform are common<sup>19</sup>.

## *Costs*

Trap installations cost approximately \$600 to \$1,000, including cost of flashboard risers, culverts and excavation. Pond construction cost depends on pond size and type of return system (if included). The range of costs found in the Yolo County area for ponds with capacities between 1.5 and 4 acre-feet is \$4,000 to \$12,000 for pond and inlet/outlet structures. Addition of native vegetation on the area around the pond would add an additional \$1,000 to \$3,000 for material, labor, and irrigation system (pers. comm., A. Carvajal to S. McCord, 1/24/05). Filter strips and riparian buffers would cost on the order of \$500 per acre per year to construct and maintain<sup>20</sup>.

Assuming local farmland has a value of \$250 per acre per year<sup>21</sup>, the cost associated with converting 2,440 acres of productive agricultural land in the Willow Slough watershed to use as a control measure would be on the order of \$610,000 per year. In terms of total land area in that watershed, the cost would be \$9/acre.

## *Other Considerations*

While tailwater recovery ponds and other sediment impoundments can work effectively to minimize pollutants entering the waterways through sedimentation and erosion, many growers are concerned about the loss of productive agricultural land and potential liability associated with the creation of additional wildlife habitat. Once habitat has been created on agricultural land, it becomes difficult to remove the habitat due to other environmental regulations and laws such as the state and federal Endangered Species Acts, state streambed alteration laws, and Corps of Engineer regulations governing wetlands. Growers and their neighbors are concerned that such control measures may attract endangered species to their property, therefore creating the potential liability for taking the species during the course of normal, cultural practices. Growers are also concerned that once created, growers lose flexibility to alter cropping practices and patterns because now the habitat may be considered a water of the U.S. or State and therefore require

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<sup>19</sup> Referenced on-line at <http://www.wsi.nrcs.usda.gov/products/waterborn-pathogens.html>.

<sup>20</sup> Cost estimate is adjusted from 1995 to 2005 costs, and adapted from NRCS (1995).

<sup>21</sup> Rental value estimate for South Sutter, Western Placer, Northern Sacramento, and Yolo Counties provided by the California Chapter of the American Society of Farm Managers and Rural Appraisers, available on-line at <http://www.calasfma.com/landvalues/2003/Reg01.pdf>.

some sort of permit for removal. There are regulatory tools such as “landowner assurances” that work with private landowners to address these concerns.

In addition, above-grade impoundments always pose a risk of dam failure. Crops could be eaten by wildlife inhabiting wetlands. Flooding of fields can accelerate leaching of pesticides, herbicides, and nitrogen, thereby increasing the risk of groundwater contamination. Vehicle access to densely vegetated riparian reaches is difficult. On the plus side, actively managing riparian vegetation provides an opportunity to selectively remove problematic invasive weeds.

Erosion control within the Bypass is actually *not* encouraged. The Bypass’ flood conveyance capacity would be reduced if sediment were not flushed regularly.

## **Remove or Stabilize Mine Waste**

*POCs addressed: mercury*

### *Description*

Various conventional technologies exist to reduce the load of contaminated sediments entering water bodies. These include:

- Erosion control – common practices such as drainage modifications, re-grading, re-vegetation and slope stabilization;
- Containment and stabilization/encapsulation – application of non-contaminated covering soils or encapsulation using soil stabilizers; and
- Removal and disposal – excavation and disposal in a landfill for highly concentrated mercury-containing wastes.

### *Benefits*

Mine waste cleanup addresses contamination of local waterways from erosion and leaching, both at mine sites and in contaminated streambanks. Mine site cleanup will be required by the Cache Creek mercury TMDL for several mercury mines in that watershed. It is estimated that on the order of 95% of the current mercury load can be stopped through effective site remediation. However, the net load reduction of total mercury entering the Bypass would be approximately 5% of the total load from that watershed, thus less than 10 lbs/yr.

### *Costs*

Remediation of the Sulphur Bank Mercury Mine by Clear Lake has taken over a decade and is still not completed. Costs to date exceed \$12 million for remediation work alone, not including numerous studies over the past two decades.

Mine remediation projects in the Cache Creek and Lake Berryessa watersheds could cost on the order of \$5 million per site, depending on the size of the site and local conditions.

### *Other Considerations*

Many of the abandoned mercury mine sites are on land now owned and managed by the USBLM. USBLM would be responsible for cleaning up contaminated areas on those properties. Private landowners, who

generally inherited similarly contaminated sites, would be responsible for their land. In both ownership situations, funding would be the primary concern.

There is currently considerable uncertainty regarding a third party's liability associated with cleaning up contaminated property. At a minimum, there would be a delay in evaluating a property owner's obligation and ability to conduct the remediation. The load reduction provided by a mine remediation project in the Cache Creek or Putah Creek watersheds would primarily benefit local water quality. Loads to the Bypass are already reduced significantly by deposition in streambanks, lakes and settling basins.

## Manage Water Resources for Water Quality Benefits

Recognizing that local water resources are heavily managed for irrigation and flood control, control measures that could improve water quality by altering water management practices are described.

### Minimize POTW Discharges to the Bypass

*POCs addressed: aluminum, bacteria, boron, mercury, salinity*

#### *Description*

City of Woodland, City of Davis, and UC Davis campus POTW effluents with relatively high salinity are discharged into Bypass tributaries or directly into the Bypass. These sources could be applied to land seasonally or discharged instead into the Sacramento River.

The City of Woodland has and may continue to investigate the viability of discharging its effluent directly into the Sacramento River near the Feather River confluence. The City of Davis is also investigating, as part of its Master Planning process, the viability of discharging its effluent directly to local farmland or into the Sacramento River south of West Sacramento.

#### *Benefits*

Salinity in the Yolo Bypass in the vicinity of removed POTW effluent discharges (Woodland or Davis) would decrease marginally during the dry season if POTW effluent were diverted out of the watershed.

#### *Costs*

Land application of wastewater would incur costs to purchase or lease the land (several thousand acres), install pipelines or irrigation channels, and manage the land and water. The City of Woodland estimated that total 20-year life-cycle costs to change its current method of effluent disposal from surface water discharge to reclamation via irrigation of fodder crops would be approximately \$90 million (ECO:LOGIC Engineering, 2003). Offsetting benefits of increased land value and crop sales were not considered.

The City of Woodland estimated that total 20-year life-cycle costs to change its current effluent discharge point from Tule Canal in the Bypass to the Sacramento River would be approximately \$18 million (ECO:LOGIC Engineering, 2003). Cost associated with installing and operating pipes from the City of Davis across the Bypass and through West Sacramento would be similar.

Local irrigation costs would increase as water would need to be imported to compensate for the loss of wastewater discharges.

### *Other Considerations*

Discharging treated effluent to land would not be effective during the wet season when soils are saturated. Recent Waste Discharge Requirements in the Central Valley have increased treatment requirements for land disposal in recognition that the water could impact drinking water aquifers.

Growers in the Bypass rely on urban runoff and municipal wastewater discharges for irrigation purposes. Removing this water supply may harm local agricultural operations.

### **Manage Water Use in Bypass Wetlands**

*POCs addressed: aluminum, mercury, organic carbon, pesticides*

#### *Description*

Wetlands have been found to effectively remove many pollutants if managed for that purpose. Various parcels within the Bypass are managed differently, creating a mosaic of wetland types. These lands can potentially be managed to improve water quality while also providing benefits such as flood retention, recreation, and wildlife habitat.

#### *Benefits*

Sediment removal efficiency in wetlands can vary with settling velocity of the particles and the hydraulic characteristics of the system, (e.g., retention time, depth, aspect ratio, percent open water area). However, wetland systems designed to remove other pollutants, such as nitrogen, typically will be over-designed with respect to suspended solids removal and systems can generally be expected to produce TSS levels close to background concentrations. Background concentrations are typically in the range of 3 to 15 mg/L and are the result of vegetation decomposition and wildlife activity. Many other POCs such as other metals, organic material and pesticides associated with sediments would also be removed.

#### *Costs*

Costs for altering wetland management practices would come from developing management plans and monitoring, in addition to any control structures. A managed wetland project would cost in the range of \$20,000-\$50,000 per acre (pers. comm., Tom Cannon, Wildlands, to S. McCord, 2/9/05).

### *Other Considerations*

Residence time, seasonality of flows, soil types, plant communities, and influent quality can all impact pollutant removal rates.

Hardness and salinity, including boron, tend to increase through wetlands by the process of evaporative concentration. Heavy wildlife use of wetlands tends to increase fecal coliform concentrations.

In a national pilot study of mercury contamination in aquatic ecosystems, USGS found that wetland density (area of wetlands per area of watershed) was the single most important basin-scale factor controlling methylmercury production (Brumbaugh et al., 2001). The only local study on this issue found that the Cache Creek Nature Preserve wetlands functioned as a clear source of methylmercury to lower Cache Creek (Slotton and Ayers, 2004). The Delta mercury TMDL is expected to recommend that there be no net increase in methylmercury loads from restored marshes and new water impoundments.

Because sulfate-reducing bacteria tend to drive the methylation process, it is believed that limiting the available sulfate could be a key to minimizing the rate of methylation. The most concentrated sources of

sulfate are mineral springs in the Cache Creek watershed (Domagalski et al., 2004). However, the highest concentration of sulfate enters the Bypass through the Ridge Cut (Schemel et al., 2002).

Costs and potential benefits of projects to control methylation cannot be generated until specific projects are identified.

## **Alter Inter-basin Water Transfers**

*POCs addressed: boron, salinity*

### *Description*

Inter-basin water transfer refers to the delivery of water from one watershed (basin) to another. Two major options are considered:

- Much of the Colusa Basin Drain water is discharged into the Sacramento River. More water could be diverted from the Drain through the Knights Landing Ridge Cut, which discharges into the upper Bypass.
- A low-flow fish passage could be constructed in the Fremont Weir. Water from the Sacramento River would be diverted continuously through the passage.

Water from Putah Creek is diverted at Lake Solano and largely transferred out of the watershed to Solano County for irrigation and potable supply. Diverting less water could provide greater dilution in lower Putah Creek and in the lower Bypass. A settlement agreement provided 50% greater flows to lower Putah Creek, along with a winter “pulse” flow to encourage salmon spawning. However, because allocations of that water have been determined by court ruling, additional flows are considered relatively unavailable.

### *Benefits*

Colusa Basin Drain water diverted into the Bypass would provide additional water for irrigation and some dilution for wastewater dischargers. Monitoring results presented above indicate that water quality of this source is similar to water found currently in the Bypass.

Sacramento River water diverted through a low-flow passage in the Fremont Weir would provide some year-around, high-quality water to the Toe Drain. This water would encourage fish to migrate upstream through the Bypass while providing some dilution for wastewater dischargers.

### *Costs*

There would be only minor costs associated with any capital improvements and maintenance associated with re-routing additional flows from the Colusa Basin Drain. Additional costs would be associated with addressing extensive regulatory compliance issues and negotiations with local water users.

Designing and constructing a low-flow passage through the Fremont Weir and purchasing water rights would incur engineering costs. Additional costs would be associated with addressing extensive regulatory compliance issues and negotiations with local water users. Current activities are aimed at determining project feasibility and estimating these costs.

### *Other Considerations*

Colusa Basin Drain water is generally considered to be of poor quality. Farmers in the Bypass are generally opposed to this project because of the potential for more regulatory concerns associated with the supply of water with relatively poor quality.

Water diverted from the Sacramento River through a low-flow passage would be designated primarily for salmon migration. It would likely not be available for local irrigation. There are no major water quality concerns with this source.

# WATER QUALITY MANAGEMENT PLAN

This section represents the management plan for addressing the prioritized POCs. The goal of the management plan is to set forth a series of actions that will result in achievement of water quality objectives appropriate for the Yolo Bypass. This plan is intended to be implemented in an “adaptive management” framework: implementing control measures to address clear problems, learning more to address important knowledge gaps, and reacting to unforeseen effects.

The general components of the plan to address water quality issues in the Bypass, generally in order of most preferable first, are as follows.

- **Implement control measures.** Implement feasible and cost-effective control measures such as described previously in this report.
- **Undertake research and special studies.** Conduct focused studies that improve the conceptual model for certain POCs or that aid in quantifying effectiveness of control measures.
- **Monitor water quality.** Monitor water quality to improve our ability to detect changes in water quality and to quantify linkages in the conceptual models for various POCs.
- **Conduct site-specific objective or beneficial use studies.** Address POCs coming from predominately natural and uncontrollable sources.
- **Participate in future stakeholder activities.** Participate in related stakeholder forums and in the development of plans and policies that directly impact water quality in the Bypass.

The following sections describe ongoing and planned activities and recommends enhancements to those activities and additional activities. Future stakeholder activities are also suggested at the end of this section. These activities also give attention to water quality in the Bypass. For low priority POCs, those that do not appear to be exceeding identified thresholds for concern, focused actions are deferred. Water quality related to these POCs will likely improve as a by-product of actions focused on improving conditions related to other POCs. The application of these components to each POC is summarized in Table 14.

Table 14. Summary of recommended options for addressing the POCs.

POC	Recommended Components for Addressing POCs			
	Controls	Study	SSO	Defer
<b>Bacteria</b>	X	X		
Total coliform				
Fecal coliform				
E. coli				
<b>Boron</b>	X		X	
<b>Metals</b>				
Aluminum	X		X	
Chromium				X
Copper				X
Lead				X
Mercury	X	X		
Selenium				X
<b>Nitrate</b>				X
<b>Organic Carbon</b>	X	X		
Total organic carbon				
Dissolved organic carbon				
<b>Pesticides and Herbicides</b>				
OCs (DDE)				X
OPs (Chlorpyrifos and Diazinon)	X			
Carbamates (Diuron and Methomyl)	X			
<b>Salinity</b>	X		X	
<b>Total Suspended Solids (TSS)</b>				X

## Implement Control Measures

The previous chapter outlined and discussed a number of potential control measures relative to the POCs. A number of the potential control measures discussed are not appropriate or practical due to the cost and other considerations related to the measure. However, some measures are appropriate and cost effective for addressing at least some of the POCs. The control measures that were determined to be applicable and effective after evaluating all of the considerations are included here as recommended activities. These control measures address multiple POCs and represent activities and projects that appear most feasible and reasonable at this time. Expected effects are described, although generally not quantified in scale or benefit because of the lack of information currently available.

### Improve Source Water Quality

*Expected Effects: Reduced loads of boron and salinity to the Bypass. Recommended investigations will determine benefits to agricultural water users in the Bypass.*

The City of Davis plans to construct four to six new deep (> 700 ft) wells during the next five years to obtain approximately 4600 acre-feet per year of water in place of water from intermediate depth wells. This water would amount to approximately 30% of the City's current annual water production. Water from deeper wells has an average TDS concentration of 380 mg/L versus 680 mg/L for water from intermediate depth wells. Therefore, salt loading in the City's water supply is expected to be reduced by approximately 3.8 million pounds per year. Water from the deep wells will also be much softer than water from intermediate

depth wells, which will in turn reduce salt usage in water softeners. The lower salinity source water and reduced water softening discharges are expected to reduce influent wastewater TDS concentrations by approximately 150 to 200 mg/L (Rob Beggs, Brown & Caldwell, pers. comm. to S. McCord, 3/4/05).

The City of Woodland has already drilled deeper test wells and found unexpectedly high salinity there (Gary Wegener, City of Woodland, pers. comm. to S. McCord, 3/17/05).

It is recommended that:

- The City of Woodland continue to investigate the benefits of constructing deeper wells for drinking water supply; and
- The Cities of Davis and Woodland continue to investigate the feasibility of obtaining rights to withdraw water from the Sacramento River.

### **Conduct Outreach and Education**

*Expected Effects: Reduced loads of all POCs. Actual water quality benefits cannot be estimated accurately.*

Outreach and education that would help to reduce POCs in the Bypass include:

- Conduct general stormwater management outreach and education;
- Conduct targeted outreach to promote IPM practices and optimal use of pesticides applied outdoors to reduce pesticide loads;
- Conduct targeted outreach to promote the use of “doggy bags” to reduce bacteria loads;
- Conduct mercury-specific outreach and education;
- Encourage alternatives to conventional water softeners in the Cities of Davis and Woodland to reduce salt loads; and
- Conduct outreach and education to potential swimmers in the Bypass, such as farm workers and recreational visitors, that bacteria levels are high and that the water is unsafe for drinking or swimming.

### **Implement Agricultural BMPs**

*Expected Effects: Reduced loads of pesticides to the Bypass. Given that agriculture appears to be the major source of pesticides in the Bypass, large-scale implementation of these BMPs are expected to significantly reduce pesticide loads.*

Several control measures should be pursued to reduce pesticide concentrations in agricultural runoff:

- Enhance IPM programs in agricultural areas;
- Encourage the use of pest resistant varieties for the various crops grown in the watershed if appropriate;
- Encourage the use of reduced risk pesticides where applicable;
- Minimize erosion and sediment transport from agricultural lands through appropriate BMPs. Also, plant fescue in tailwater drains where practical to enhance particle setting;
- Implement irrigation and pesticide application BMPs to minimize runoff of pesticides; and
- Encourage farmers to limit use of more water-soluble pesticides (OPs & carbamates).

## **Implement Livestock BMPs**

*Expected Effects: Reduced load of pathogens to the lower Bypass.*

Investigate the feasibility and benefits of livestock BMPs that minimize discharges of manure to waterways in the Bypass. This BMP would focus on the approximately 9,000-acre area in the southern Bypass on which cattle graze.

## **Support Enhancements to the Cache Creek Settling Basin**

*Expected Effects: Reduced load of metals to the Bypass. Total mercury loads could be reduced by an additional 20% beyond the Basin's current removal efficiency.*

Enhance and/or maintain the Cache Creek Settling Basin to reduce sediment loads. Ancillary benefits would be to reduce loads of sediment-associated POCs including aluminum, mercury, and some pesticides;

## **Develop and Enforce New Development Guidelines**

*Expected Effects: Reduced load of bacteria, organic carbon, and pesticides to the Bypass. Benefits are more likely to be realized locally rather than in the Bypass.*

Minimize POC loads from new urban development by implementing municipal stormwater management plans' new development programs.

# **Undertake Research and Special Studies**

Several knowledge gaps have been identified through the evaluation of available information and the development of this plan. Results from the ongoing or planned studies described in this section will improve the conceptual models for POCs and thereby provide a better foundation for future control actions. Recommendations for improving or focusing the studies to improve the conceptual model for various POCs are also provided.

## **Conduct Pilot Sediment Study in the Northern Yolo Bypass**

At Fremont Weir, accumulated sediments have been removed in 1986, 1987, and 1991, from the west, central, and east portions, respectively, restoring the areas to design grade. In the 2005-2007 period, 1-3 ft of sediment will be removed from the west and central portions again, to a distance approximately 3/4 miles south of Fremont Weir. DWR is conducting a pilot study to look for trends in quantity and types of sediment that drop out near the weir, trying to identify the primary water source of the deposited sediment.

It is recommended to measure aluminum, mercury, and pesticides in soils as part of this study. Broaden the spatial scale to encompass other areas in the Bypass if funds allow.

## **Conduct Colusa Basin Drain Diversions Study**

Numerous stakeholders have come together to develop a proposed two-phase study to evaluate water quality within the Colusa Basin Drain, as well as eventually to evaluate the potential benefits of discharging into the Yolo Bypass instead of into the Sacramento River. The first phase will characterize the water in the Drain and consider the effects of its discharges on downstream users. A data summary report of accumulated information from such sources as local water districts, the USGS, state and regional

regulators, DWR, California Department of Pesticide Regulations, California Rice Commission, City of Woodland, and CA Department of Fish and Game regarding the flow and water quality in the Colusa Basin Drain and the Knight's Landing Ridge Cut is scheduled for completion in early 2005. The results of this study will guide future monitoring activities that the stakeholders may propose. Depending on the results of Phase 1, the second phase will consider alternatives for improving water quality for downstream users.

Recommendations for Phase 2 are to:

- Include monitoring for all high and medium priority POCs; and
- Address the potential impacts of additional mercury load caused by diverting additional water from the Colusa Basin Drain through the Bypass.

### **Conduct Sediment Methylation Study**

The USGS, in collaboration with other project partners, is planning a field study to measure mercury methylation rates in various wetlands. A summary of this project is not yet available.

### **Conduct Wetland Management Study**

Wildlands, Inc., owns and manages a 400-acre property just south of the Knights Landing Ridge Cut. They have water rights totaling approximately 10 cfs and can manage the property as they see appropriate. Consequently, Wildlands has practically unrestricted access to and control over the land and water supplied to it. Wildlands has proposed to conduct an adaptive management experiment to treat Knights Landing Ridge Cut water through its wetlands.

It is recommended to track progress in this study, if funded.

### **Investigate Vector Control Pesticides**

Vector control pesticides are applied in and adjacent to the Bypass under certain circumstances. It is recommended to investigate the potential loads of these pesticides.

### **Conduct Desalinization Research**

Research is underway at a national level to reduce the cost of RO brine disposal. The focus is on reducing the amount of energy consumed to operate with zero liquid discharge using dual-stage RO units, crystallizers, and solar evaporation ponds (ASCE, 2005).

It is recommended to track results of research and pilot studies that address RO treatment systems and brine disposal.

### **Conduct Bacteria Special Study**

With respect to bacteria source loads from wetlands, a substantial portion of the measured total coliform load appears to be from waterfowl. Because waterfowl and wetlands are generally encouraged, it must be recognized that the deleterious coliform by-product may be largely unavoidable.

It is recommended to investigate the feasibility of attaining current bacteria objectives in the Bypass. If attainability is infeasible, conduct a use attainability analysis pursuant to USEPA regulations to determine if

de-designation of the swimming use (REC-1 water contact recreation) is appropriate. Agricultural uses will remain problematic.

It is also recommended to conduct a bacteria source tracking study. The first step is to characterize the measured levels of bacteria as human or non-human origin. The next steps would be (1) to characterize non-human bacteria further, such as distinguishing bird sources from cattle sources, and (2) to determine the presence or absence of human viruses.

### **Conduct Salinity Source Control Study**

No feasible control measures that could effectively reduce salinity loads from agricultural areas have been identified. It is possible that the Cities of Davis and Woodland and UC Davis could reduce salinity levels in wastewater effluent through source control. However, the actual water quality improvement in the Bypass would be negligible. These entities should conduct salinity source control studies, with a focus on any significant industrial or commercial sources and water softeners. Results from this study may justify the development of SSOs for salinity and boron in the Bypass. The City of Woodland is currently investigating salinity sources in its service area.

It is recommended to:

- Support the City of Woodland salinity source identification study; and
- Support the UC Davis EC study being funded by the Cities of Davis and Woodland.

### **Conduct Tertiary Treatment Benefits Study**

It is recommended to investigate the costs and benefits of installing tertiary treatment processes at the City of Davis and City of Woodland municipal wastewater treatment facilities in relation to reducing bacteria loads and/or protecting recreational and agricultural uses in the Bypass.

### **Investigate Feasibility of Improving Migratory Fish Passage**

Salmon have been found in lower Putah Creek in late 2003 and 2004 in response to pulsed flows from Lake Berryessa. Projects to open Cache Creek and the Fremont Weir to fish passage are in various stages of development. The impacts of altering flows, particularly through Fremont Weir, on water quality are generally expected to be beneficial. How these projects impact the needs for proposed control measures is undetermined.

It is recommended to participate in the development and implementation of plans to enhance fish passage through the Bypass.

### **Develop a Water Quality Model for the Bypass**

Our ability to quantify water quality conditions in the Bypass, with a reasonable level of statistical assurance, is restricted now by the disparate condition of the available data. Developing a numerical model of the Bypass' hydrology, sediment transport, and pollutant loads would be feasible by linking the available hydrologic model with a comprehensive water quality database. All of the special studies and monitoring planned or recommended as part of this plan would be used as input to the model.

## Monitor Water Quality

Monitoring water quality regularly over a long period and at multiple locations provides an opportunity in the future to detect changes in water quality and to quantify linkages in the conceptual models for various POCs. Other entities have been monitoring water quality in the Bypass concurrent with this project. Because results from those activities are not yet available, several are noted here for future reference.

### Monitor Water Quality in the UC Davis Campus Arboretum Waterway

Since the UC Davis Campus Arboretum Waterway ("Arboretum") receives no inflows during dry weather, except for incidental irrigation overflows, algae blooms are common during the summer months. The campus is currently planning a project to reroute treated water from the UC Davis campus wastewater treatment facility through the Arboretum to provide a source of fresh water during dry weather. The design would also allow for treatment of Arboretum water by the treatment facility when excess capacity is available (e.g., at night). This project is intended to improve water quality in the Arboretum, and support possible water reclamation projects on campus in the future. However, the potential for methylmercury generation through the arboretum should be recognized and addressed by monitoring the influent and effluent from the Arboretum to assure that there is no significant net increase in methylmercury being discharged.

### Monitor Local Methylmercury Concentrations

The Cities of Davis and Woodland have been requested by the Regional Board to characterize methylmercury concentrations in the effluent from their wastewater facilities. If concentrations are elevated then the Cities may be requested to conduct special studies to determine how to reduce those concentrations.

Yolo County has monitored mercury and methylmercury in and around the Cache Creek Nature Preserve for the past three years (fall 2000 through summer 2003) and just renewed the effort for another three years. Additional mercury monitoring may be required as part of the Cache Creek mercury TMDL.

### Monitor Pesticide Concentrations in Bypass Inputs

USGS is currently measuring pesticide concentrations in the various inputs to the Yolo Bypass, including Knight's Landing Ridge Cut, during the winter.

### Monitor Receiving Waters for NPDES Permittees

Wastewater discharges regulated under the NPDES permitting program monitor their effluent and receiving water quality on a regular basis. Monitoring frequency, constituents monitored, and sample locations are determined based on site-specific water quality concerns and spelled out in individual permits.

Municipalities and owners of construction sites disturbing greater than one acre of land are required to obtain coverage under separate NPDES stormwater permit programs. No monitoring is required of these permittees unless problems are identified. While urban uses of OP pesticides have been phased out, homeowners generally select other available pesticides rather than use other pest control measures. Any future monitoring of water quality in urban runoff should include analyses for current use pesticides.

## **Monitor Under the Agricultural Discharge Permit Waiver Program**

The Conditional Waiver for Irrigated Lands in the Central Valley has a monitoring requirement that has resulted in the development of additional monitoring sites within the Yolo Bypass. The Yolo County agricultural community is working with the Sacramento Valley Water Quality Coalition to coordinate the monitoring requirements contained within the Conditional Waiver. The agricultural waiver program requires dischargers to conduct a toxicity identification evaluation if significant toxicity is found after a resampling event. Three sites monitored for this study are also being monitored for the agricultural waiver program using the 96-hour exposure test: Toe Drain, Z Drain, and Tule Canal. No additional monitoring beyond these requirements is recommended.

## **Monitor Bypass Hydrology and Geomorphology**

DWR regularly monitors hydrology and geomorphology, water quality, aquatic resources, and terrestrial resources in the Bypass. Water quality indicators monitored include Secchi depth, conductivity, temperature, pH, and Chlorophyll *a* (all at the Little Holland "stairstep", which is downstream of the Toe Drain sample site); plus nutrients, cations, and organic matter (all at three sites in the Bypass along the eastern margin of the Yolo Bypass and in local tributaries Ridge Cut, Cache Creek, Willow Slough, and Putah Creek). They also store these data in the Bay Delta and Tributaries (BDAT) database (<http://bdat.ca.gov>). Monitoring is not occurring now, but will be again starting in 2006 pending CALFED funding approval.

## **Monitor to Estimate Mercury Loads**

The Regional Board is collecting mercury data in the Bypass under a CALFED-funded project to estimate a mercury mass balance of the Delta. One of the project's aims is to develop more detailed mass balances for these areas: 1) above Lisbon, 2) Lisbon to start of flooded islands, and 3) in the flooded Liberty and Little Holland Tracts (Chris Foe, Regional Board, pers. comm. to S. McCord, 3/4/05).

## **Conduct Fish Tissue Sampling**

The concern for some POCs, particularly pesticides and mercury, is bioaccumulation and its effects on top predators. However, no comprehensive monitoring of resident fish species has been conducted. A special study to assess fish body burden of bioaccumulative POCs and other potential POCs such as trihalomethanes is recommended. This information would serve to improve the understanding of pollutant fate in the aquatic food web and to support fish consumption advisories.

## **Develop a Sustainable Baseline Water Quality Monitoring Program**

All of the monitoring activities described in this section are focused in time and location. The benefits of a comprehensive, regular monitoring program would be to track progress towards attaining water quality objectives and to put short-term or spatially limited monitoring results in perspective. Routine monitoring should be conducted to improve the understanding of baseline conditions, track water quality trends, and identify new POCs.

## Conduct Site-specific Objective or Beneficial Use Studies

Changes in water quality standards may be appropriate for aluminum, salinity and boron because the current standards are either infeasible or not applicable. Water quality standards may be changed by altering the designated beneficial use (which changes the applicable water quality criteria), developing a site-specific water quality objective, or both. In any of these cases, a study would need to be conducted to support a change in the water quality standard and ultimately amend the Basin Plan.

To change a beneficial use designation, a Use Attainability Analysis (UAA) would need to be prepared. Under federal regulations, a beneficial use may be de-designated if it can be demonstrated that the designated use is not attainable because:

- Naturally occurring pollutant concentrations prevent the attainment of the use; or
- Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or
- Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
- Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
- Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
- Controls more stringent than those required by sections 301(b) and 306 of the Act (Clean Water Act) would result in substantial and widespread economic and social impact. (40 CFR 131.10 (g) and (h)).

Changes in water quality objectives, or the development of a site-specific water quality objective for a specific water body, are governed by federal and state law, and must be approved by USEPA. In California, water quality objectives must “ensure the reasonable protection of beneficial uses and the prevention of nuisance.” When adopting or changing water quality objectives, the Regional Board must consider a number of factors, which include:

- Past, present and probable future beneficial uses of water;
- Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;
- Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;
- Economic considerations;
- The need for developing housing within the region; and
- The need to develop and use recycled water. (CA Water Code §13241.)

In other words, a change in a water quality objective must still provide reasonable protection for the beneficial uses designated within the Basin Plan.

Another option is to change the water quality objective as it is documented in the Basin Plan. Some dischargers may be able to change a water quality objective or criteria *as it applies to them* in a permit or a basin plan amendment through the development of a Water Effects Ratio (WER). The development of a site-specific objective through a WER is usually associated with numeric water quality criteria for metals developed by USEPA for aquatic life species. In general, the national numeric water quality criteria developed by USEPA are derived through a literature review of aquatic toxicity studies and tests performed in laboratory waters that often are not representative of natural waters. The USEPA acknowledges that because of a variety of physical and chemical characteristics of water bodies (e.g. pH, hardness, alkalinity, suspended solids, salinity, etc.) throughout the country that the national criteria might be either under- or over- protective for some water bodies. WERs are used to account for “real-world” conditions that may impact the toxicity of metals towards aquatic life. USEPA guidance has outlined three procedures that can be used to derive site-specific objectives in these circumstances.

- The **Recalculation Procedure** is intended to take into account relevant differences between the sensitivities of aquatic organisms in the national data set and the sensitivities of organisms that occur at the site.
- The **Indicator Species Procedure** provides for the use of a WER that is intended to take into account relevant differences between the toxicity of the metal in laboratory dilution water and in site water.
- The **Resident Species Procedure** is intended to take into account both differences in sensitivities of aquatic organisms and differences in toxicity of laboratory dilution water and site water. (USEPA, 1994).

Potential studies necessary to implement changes in beneficial uses or water quality objectives for specific pollutants are discussed further below.

## Aluminum

Aluminum may be a viable candidate for the development of a site-specific objective through a WER for several reasons. First, the national recommended ambient criteria of 87 ug/L for aluminum is a qualified criterion that may not be applicable in all watersheds. The USEPA's 1998 National Recommended Water Quality Criteria for aluminum contains a footnote to the 87 ug/L that documents why a WER might be appropriate for aluminum in some situations like the Yolo Bypass. In particular, the footnote states that the 87 ug/L value is based on a toxicity test with striped bass in water with a low pH (6.5-6.6) and low hardness (< 10 mg/L). The average pH and hardness for the in-Bypass monitoring sites was 8.0 and 223 mg/L, respectively, indicating that a WER is appropriate.

Excluding outliers in the dataset, the aluminum concentrations of in-Bypass water samples approximates the natural aluminum content of native soil. The recommended control measures are not expected to reduce aluminum concentrations sufficient to achieve the recommended criterion. Moreover, the aluminum associated with native soil may not be reactive (i.e., toxic) to aquatic biota. Therefore, aluminum should be addressed by developing a site-specific objective, specifically a Water-Effect Ratio (WER) using USEPA protocol.

The WER would effectively take into account the local water quality characteristics that mitigate toxicity of aluminum to aquatic life. Initial work should consist of range-finding toxicity tests, whereby several candidate species of aquatic biota would be evaluated for use in the actual WER testing. Based on results of the range-finding tests, a small number of species could be selected for the WER tests. Subsequent work would entail performance of the actual WER study using the selected species along with consultation with and evaluation by an expert review panel.

## **Boron and Salinity**

Salinity and boron may be eligible for site-specific objectives and basin plan amendments because the criteria interpret a narrative objective by using a United Nations report's recommended Agricultural Goals. The United Nations report clarifies that the most conservative goals for salinity and boron are intended to apply worldwide, regardless of the climatic conditions and that the actual level of salinity and boron may change depending on a number of factors including rainfall and other natural conditions. In response to issues and concerns raised regarding the applicability of the recommended goals contained in the United Nations report to the Yolo Bypass area, the State and Regional Board are working with dischargers in the Yolo Bypass area to determine what may be an appropriate objective for the reasonable protection of the agricultural beneficial use.

In order to determine what may be an appropriate level of protection, UC Davis researchers have developed a model to determine how the EC of a given irrigation water supply affects crop production while taking annual rainfall into account (Isidoro-Ramirez et al., 2004). The referenced report marks the completion of work initially proposed by UC Davis to the Regional Board in January 2003. The model relates the EC of the irrigation water to the seasonal average root zone salinity, expressed as the electrical conductivity of the saturated paste. The model considers the timing and quantity of applied irrigation water, the quantity and distribution of rainfall, and realistic assumptions related to soil water principals based on soil type. This model was used to evaluate site-specific conditions for the Putah Creek reach downstream of the UC Davis treatment plant based on consistently conservative assumptions. Model results from simulating yields of salt-sensitive crops over the past 53 years of rainfall indicate that using 1,100 uS/cm as the threshold EC value for irrigation water is considered protective for all agricultural uses of the water in the area. These same researchers are in the process of developing protective EC values for the Yolo Bypass.

In addition, the UC researchers are working with boron experts from the University of California, Riverside to determine how the model may be adjusted to determine appropriate and protective values of boron for the Yolo Bypass area.

Once the studies have been completed, UC Davis, the Cities of Woodland and Davis and other stakeholders will work with the Regional Board to determine if a basin plan amendment is necessary to implement the objectives developed through the study process.

## **Participate in Future Stakeholder Activities**

Several future stakeholder activities are recommended for inclusion in the Water Quality Management Plan in this section. The activities provide mechanisms for tracking and participating in the development and implementation of projects that impact water quality in the Bypass.

## **Conduct Stakeholder Meetings**

Stakeholders, such as those comprising the Stakeholder Advisory Group, should meet on a regular basis to provide a forum for tracking ongoing studies and monitoring, to coordinate activities, and to share results of the recommended control measures and studies.

## **Develop a Master Yolo Bypass Water Quality Database**

As monitoring activities increase, so does the need for accurate and expedient data management. Enhanced data management can be achieved through the development of a relational database designed to store and manage the monitoring data. A comprehensive data management application would need to satisfy the following data management objectives: (1) efficient storage of all data in a geo-referenced format, (2) enhanced data validation and qualification of water chemistry environmental data through the “onboard” storage and evaluation of water chemistry QA/QC data, (3) robust data manipulation and analysis capabilities through user-friendly graphical user interfaces (GUIs), (4) capability to upload to the SWAMP database, and (5) the capability of the application to be modifiable as needs change over time. The ultimate goal of a database would be to provide a powerful, easy-to-use water quality data management system to stakeholders in implementing the Yolo Bypass Water Quality Management Plan.

## **Track and Participate in the Development of Relevant Environmental Management Plans and Policies**

Several plans and policies that impact water quality management in the Yolo Bypass are under development. The most relevant projects are described in this section, in order of larger to more local focus. It is recommended that stakeholders track or participate in the development and implementation of these plans and policies.

### *California Drinking Water Policy*

Drinking water is regulated by the California Department of Health Services, which issues drinking water standards, and the State and Regional Boards, which designate waterways as having beneficial use of municipal and domestic water supply and protect them for those beneficial uses. Current plans and policies lack water quality objectives for several known drinking water constituents of concern and implementation strategies to provide effective source water protection. A multi-year effort is underway to develop a drinking water policy for surface waters in the Central Valley. The Central Valley Drinking Water Policy Workgroup, formed to develop and implement a work plan to provide the technical information needed by regulators to develop appropriate policy. Work plan tasks include water quality monitoring, pollutant load evaluations, and evaluations of potential control strategies to identify those that are reasonably attainable and cost effective.

### *Sacramento River Watershed Program*

The mission of the non-profit Sacramento River Watershed Program (SRWP, see <http://www.sacriver.org/>) is to ensure that current and potential uses of the watershed’s resources are sustained, restored, and where possible, enhanced, while promoting the long-term social and economic vitality of the region. The SRWP provides a network for building a basin-wide context to improve watershed health. It operates through consensus-based collaborative partnerships, coordination of research and monitoring, and enhancing mutual education among stakeholders. Recognizing that flood waters to the Bypass come from the Sacramento River watershed, this larger stakeholder group is an important link to source water quality.

### *Yolo County Integrated Water Resources Management Plan*

The Yolo County Integrated Water Resources Management Plan (IRWMP) currently in review will update the County's 1992 water management plan. The IRWMP also will explore opportunities for cooperative action, serve as a countywide forum to identify and address concerns related to water resources, and help provide a framework under which local water management policies, projects, and programs could be formulated, evaluated, and implemented. Local agencies and stakeholders in Yolo County have been working together with DWR to complete this plan.

Volume 1 of the IRWMP provides information about the physical, institutional, and legal aspects of water management in Yolo County, including the management of water for agricultural, municipal, and environmental purposes. Volume 1 uses background information and data from existing reports, studies, programs, investigations, and planning efforts.

Volume 2, to be completed in 2006, will build upon the information provided in Volume 1. Volume 2 will contain an implementation plan to address surface water, watershed, groundwater, water supply reliability, and other water and environmental resources issues. Volume 2 will involve considerable stakeholder input to develop the plan.

### *Cache Creek Resources Management Plan*

Yolo County has many on-going efforts to preserve its environmental lands including the Open Space and Recreation Element of the General Plan, the Habitat Conservation Plan, and the Cache Creek Resources Management Plan (CCRMP). Of these, the CCRMP is the most relevant for this plan because it specifically addresses water management and water quality. The CCRMP addresses a variety of issues relevant to managing the diverse resources within the Creek Channel from the Capay Dam to near the town of Yolo. The CCRMP drives land use activities and environmental restoration within the present channel banks and 100-year floodplain. Adoption of the CCRMP discontinued commercial mining within the active creek channel. The CCRMP also aims to:

- Improve channel stability;
- Minimize flood damage;
- Restore wildlife;
- Prescribe standards and regulations for initial channel smoothing and shaping;
- Recommend ongoing maintenance activities and creek restoration efforts;
- Provide year-round flows in many portions of the creek;
- Identify restoration project areas; and
- Provide buffers for existing and future agricultural for restoration and recreation areas.

### *Willow Slough Watershed Resources Management Plan*

A planning process was initiated by the Yolo County Resource Conservation District, Yolo County Flood Control and Water Conservation District, Yolo County Community Development Agency, and the California Wildlife Conservation Board to explore the possibilities for managing natural resources throughout the Willow Slough watershed in an integrated manner. This two-year process involved the participation of numerous landowners; federal, state, and local agencies; and the general public, and culminated in 1996 with the development of a draft plan document. A final report is in progress (pers. comm., P. Robins to S.

McCord, 1/19/05). The list of possible implementation measures is organized into the following general categories:

- Construct impoundments,
- Manage riparian vegetation,
- Modify slough channels,
- Improve rangeland,
- Alter cultivation practices, and
- Implement other possible measures.

#### *Yolo Bypass Wildlife Area Management Plan*

The California Department of Fish and Game will begin a two-year project to prepare a wetland management plan for the Yolo Bypass Wildlife Area. Major goals for the plan are to:

- Provide for permanent flowing water;
- Restore wetlands to their natural function;
- Generate operating income through seasonal agriculture;
- Study mercury methylation in wetland environments; and
- Study management effects on salinity and pesticide concentrations in wetland runoff.

#### *TMDLs*

The only relevant TMDLs being developed by the Regional Board are for mercury in Cache Creek and the Delta. Phase 1 of the Cache Creek TMDL calls primarily for additional study, but the intent for Phase 2 is to reduce methylmercury concentrations and sediment mercury content eventually. The Delta TMDL will likely impose load and waste load allocations to sources of methylmercury into and from the Bypass.

It is recommended to participate in the development and implementation of the Clear Lake, Cache Creek, and Delta mercury TMDLs.

#### **Pursue Water Quality Trading**

It is recommended to promote the concept of water quality trading as a viable mechanism for implementing load reduction projects.

#### **Address New POCs**

Water quality impacts to the Yolo Bypass change over time because of several complex and dynamic processes, triggered by such things as agricultural practices, urban development, climate change, catastrophic events, and water management. In this dynamic environment, the list of POCs will likely change over time. The proposed research and monitoring programs will help to identify and quantify those POCs.

The same contacts used to call upon stakeholders convened for the development of this plan should be utilized to call for participation in addressing POCs identified in the future.

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